Nuclear Proliferation and Safeguards: Appendix Volume II, Part Two

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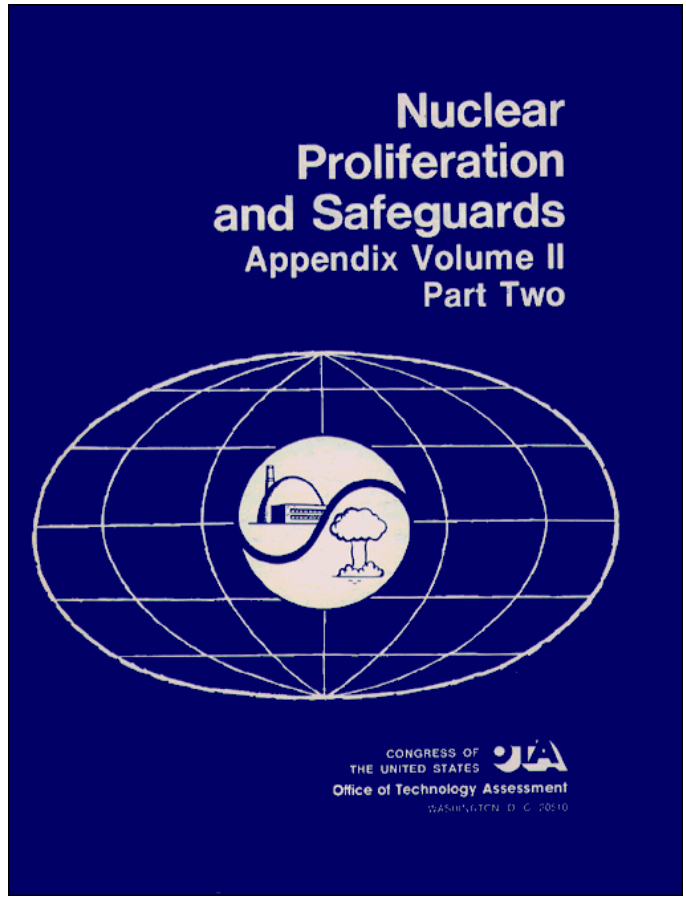

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APPENDIX VI-A

DEDICATED FACILITIES FOR THE PRODUCTION OF NUCLEAR WEAPONS IN SMALL AND/OR DEVELOPING NATIONS

by

John R. Lamarsh

NOTE: portions of this report are based on material prepared earlier for the Congressional Research Service of the Library of Congress.

I INTRODUCTION

Preventing the spread of nuclear weapons to other nations has been a-major policy objective of the United States Government since the end of World War II. This objective has found expression in domestic legislation restricting the export of nuclear technology and materials, and, on the international front, in the establishment of the International Atomic Energy Agency (IAEA) and in the negotiation of the Treaty on Nonproliferation of Nuclear Weapons (NPT).

With the increasing pace in the construction of nuclear power plants abroad, considerable attention has been given to the problem of assuring that none of the plutonium produced in these plants is diverted for use in weapons. Indeed, the NPT requires continuing IAEA inspection of nuclear power plants in signatory nations that currently do not have nuclear weapons.

However, the NPT alone cannot prevent the proliferation of nuclear weapons if these weapons can be produced outside the mainstream of the nuclear industry in facilities specifically dedicated to their manufacture. It appears that this, in fact, is the case. As shown in this report,

many nations in the world today, in particular, many small and/or developing nations, are capable of undertaking nuclear weapons programs that can provide them with a small number of weapons in a period of five to ten years.

It is reasonable to assume that any nation which embarked on a program to procure nuclear weapons would attempt to keep this fact a secret as long as possible.

A nation that can suddenly demonstrate a nuclear capability has an obvious advantage over an unsuspecting adversary. At the same time, a clandestine weapons program avoids the recriminations and international political pressures that the nation might encounter if it pursued the program openly.

Throughout the present report, therefore, it will be assumed that any nuclear weapons program must be kept secret. As will be seen, this severely restricts the kind Of weapons producing facilities that can be built, their size, rate of production, and location.

II PRODUCTION OF NUCLEAR WEAPONS MATERIALS

The explosive material in an fission nuclear weapon (as opposed to a hydrogen bomb) can be either plutonium-239 or uranium that has been enriched in the isotope uranium-235, or uranium-233. In order to make a nuclear weapon it is necessary, therefore, to procure one or the other of these substances in the necessary amounts. About 5 to 10 kilograms are required for a plutonium bomb; about 15 to 30 kilograms for a U-235 explosive.

Plutonium-239 is not a naturally-occurring substance. It is manufactured from the isotope uranium-238 in an operating nuclear reactor. The newly-produced plutonium-239 is then separated chemically from the uranium. Virtually all power reactors operating in the world today contain large amounts of uranium-238, so that these reactors are automatic producers of plutonium-239. A typical American light water reactor in a nuclear power plant generating 1000 megawatts of electricity produces about 250 kilograms of plutonium-239 per year.

Plutonium-239 was first obtained for use in nuclear weapons in the United States during the Manhattan Project of World War II from specially-designed plutonium production reactors. It appears entirely possible for many small and/or developing nations to obtain plutonium in a similar way, by

building a small plutonium producing reactor and associated plutonium recovery plant. These matters are covered in Sections 111 and IV.

The enriching of uranium by such a nation would seem to be a more difficult undertaking than the production of plutonium in a small reactor. There are several methods that might be considered for enriching uranium. To date, the most successful method is the gaseous diffusion process, which was also A developed by the Manhattan Project in World War II. This has remained essentially the only source of enriched uranium for military and civilian nuclear programs since that time, both in the United States and abroad. However, gaseous diffusion plants are inherently large Structures that utilize a relatively sophisticated technology, much of which remains classified, they require an enormous investment of capital, and consume large amounts of electric power. And, of course, they cannot be concealed. 'She gaseous diffusion route to nuclear explosives is simply out of the question for all but a handful of the largest and developed countries, and will not be considered further in this report.

The use of high-speed centrifuges to separate the isotopes of uranium, a method that was explored during the Manhattan Project but later abandoned, has re-emerged in

the last few years and appears to be more economical than gaseous diffusion. This method is discussed in Section V of this report.

Another method for enriching uranium is the Becker nozzle process. A variation of this method is being used in the Union of South Africa.

However, this method requires a large number of stages (see discussion of stages in Section V) and consumes two and one-half times as much electric power as gaseous diffusion and about thirty times as much as centrifuges. About the only attractive feature of the Becker method is that it is totally unclassified. In any case, this method does not appear to be a reasonable choice for a small and/or developing nation.

A number of other processes for separating uranium are under development that promise to reduce substantially the cost of enriching uranium. Since these have not been demonstrated in practice, they are not available options for small and/or developing nations in the near future.

III PLUTONIUM-PRODUCING REACTORS

As noted earlier, plutonium-239 is produced in any operating nuclear reactor containing uranium-238. The first problem therefore facing any nation embarking upon an illicit nuclear weapons program based on plutonium is to obtain the necessary nuclear reactor. India received a research reactor from Canada, and by introducing their own uranium-238 into that reactor, the Indians were able to produce enough plutonium to make a bomb. The fact that Indian uranium was used to produce the plutonium presumably circumvented in a legal way the safeguards provisions in the Canadian-Indian reactor agreement. In much the same way, Israel procured a small research reactor from France, and according to some reports this reactor has provided the Israelis over the years with enough plutonium for between 10 and 20 bombs.

No doubt, the Indian and Israeli experience will make it more difficult for other nations to obtain reactors in the future, outside of the provisions of the NPT. The question remains, then, how difficult would it be for a

nation, lacking a major technological base, to construct a plutonium-producing reactor on its own.

The problems which must be solved by such a nation in building a production reactor closely parallel those faced by the United States and her allies in the Manhattan Project - with two important exceptions: (1) the necessary reactor technology is highly developed and readily accessible in the open literature, and (2) important materials unavailable at the beginning of World War II can now be purchased on the free market.

The first issue that the nation's leaders would have to settle is the number of bombs that they felt the nation must acquire and the time scale for getting them. These factors determine the size of the reactor - assuming for the moment that only a single reactor is under consideration. It is shown in Annex A that the rate of plutonium production is proportional to the reactor power level. For example, a reactor operating at 25 megawatts (MW) will produce between 9 and 10 kilograms of plutonium per year, enough for one or two bombs. As outlined below, such a reactor can be built and operated at nominal cost, in a relatively short time, with a small number of personnel, and there is at least a fair chance that its existence could be concealed for several years.

A more ambitious program, one which would yield, say,

between 10 and 20 bombs per year would require a reactor operating at 200 to 500 MW. The construction of a reactor of this size would be a major undertaking. It would necessitate a large investment in capital, take a long time to complete, and involve a large number Of engineers and construction workers. There is no chance that the project could be kept secret, either during construction or in operation. What is more, while the 25 MW reactor could be built according to plans of a reactor that was actually operated for many years, a good deal of design and engineering would have to be done on the larger reactor, and there could be no guarantee beforehand that the reactor would operate successfully. Finally, there is the question as to what a small and/or developing nation could possibly do with so many bombs. After 10 years of operation the nation could have as many as 200 weapons, far more than needed to obliterate any other small and/or developing country. Yet, even then, it would be difficult to abandon such an enormous reactor and its associated plutonium recovery plant into which the nation had poured so much wealth.

In short, it does not appear reasonable to assume that the nation in question would attempt to build a large

reactor, and if they elected to do so there is little reason to expect that they would achieve their objective.

One additional factor should be mentioned. If the nation were successful in constructing: the smaller reactor and required a higher plutonium production rate, there is nothing to prevent it from building a second or third reactor of 'the same type. Having built one reactor, it would be an easy matter to build carbon copies.

Since the nation in question would not have access to enriched uranium- if they were able to produce enriched uranium the y would never "bother to produce plutonium - the reactor would have to be fueled with natural uranium. This automatically places restrictions on the type of reactor that can be built. I t either has to be moderated with graphite o r with heavy water- t hes e are the on 1 y practical moderators that can be used in a natural uranium fueled reactor.

However, heavy water has drawbacks. It is expensive and obtainable from only a handful of countries. Attempts to purchase it would immediately reveal an intention to undertake a nuclear program, since the necessary amounts of heavy water could have no other possible application. The construction of a heavy water production plant requires relatively sophisticated technology, and would be a

difficult task for a small and/or developing nation. At the same time, the technical problems of designing, building, and operating a heavy water reactor are somewhat more formidable than for a graphite reactor with the same plutonium production capacity. For one thing, the reactor vessel, with its many piping connections and instrumentation and control penetrations, must be leak tight to prevent the loss of heavy water. This requires high-(grade manufacturing skills presumably not present in the nation in question. While the Indian and Israeli reactors are Of the heavy water type, both were obtained from nations having long experience in fabricating heavy water reactor systems. It may be concluded, therefore, that the plutonium producing reactor would be graphite moderated.

It must be next decided how the reactor would be cooled. Amens several possibilities, only air and water are practical choices for the reactor coolant. Other coolants, such as CO_2 or helium require closed cycle operation, an unnecessary complication for a reactor operating at low power levels. Water-cooled reactors are capable of higher plutonium production rates than air-cooled reactors of the same size, because water has better cooling properties than air. However, a water-cooled reactor is more difficult to design, construct,

and maintain. Water is more corrosive than air so the fuel elements must be carefully fabricated. The safety analysis of such a reactor is also more involved than for a comparable air-cooled reactor. Both the United States and the U.S.S.R. use water cooling in their production reactors, but these are, after all, major technological nations. On the other hand, Great Britain and France used air, at least initially, in their reactors. It seems reasonable, therefore, to assume that a small and/or developing nation would base its plutonium production program on the construction of at least one natural uranium fueled, graphite-moderated, air-cooled reactor. Another factor favoring this choice of reactor is that the design parameters for successful reactors of this type are freely available in the open literature.

The first natural uranium, graphite reactor was the so-called CP-1 pile, built by Enrico Fermi and his associates in Chicago in 1942. This was also the world's first reactor.* The CP-l was dismantled after only 4 months of operation and reconstructed as the CP-2 reactor, another experimental system of Fermi design. The first reactor to operate at a significant power level - about 2 MW - was the X-10 reactor at Oak Ridge. The purpose of this reactor was to provide plutonium for the startup phase of the plutonium chemical separation plant at Hanford,

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*Except for the naturally occuring Oklo Reactor.

Washington, prior to the operation of the Hanford production reactors.

The X-10 reactor also served as the basis for the design of the original Brookhaven Graphite Research Reactor (BGRR), which operated at Brookhaven National Laboratory from 1948 until 1957, when its natural uranium fuel was replaced by enriched uranium. The reactor was shut down in 1969 and decommissioned shortly thereafter. While the BGRR was used primarily for research, about 9 kilograms Of plutonium-239 were produced per year in the reactor - sufficient for the fabrication of one or *two bombs* per year, when process losses are taken into consideration.

The construction of either an enlarged X-10 reactor or a simplified version of the BGRR would appear to be the most logical way for a small and/or developing nation to initiate the production Of plutonium. Since the BGRR has been more widely discussed in the open literature, only this reactor will be considered in the present report.

Before doing so, however, it should be pointed out that the plutonium produced in a BGRR in the first few years Of operation is almost entirely pure plutonium-239. Very little of the plutonium-239 is converted into the heavier isotope plutonium-240. After one year of operation, for example, less than one-half of one percent of the

plutonium in the BGRR is plutonium-240. This is in marked contrast to the plutonium produced in power reactors. Because these reactors operate at much higher neutron fluxes, a substantial amount of the plutonium-239 is converted to plutonium-240. The plutonium in the fuel discharged from a power reactor following a year of operation is typically 10 to 20 percent plutonium-240.

The plutonium-240 content is an important consideration when plutonium is to be used for the manufacturing of nuclear weapons. This is because the spontaneous fission rate of plutonium-240 is so high. The neutrons emitted in spontaneous fissions can lead to the preinitiation of the explosion. In short, the plutonium produced in the BGRR is excellent bomb material; the plutonium produced in an ordinary power reactor is not as good. (See Chapter VI of Vol. I “Nuclear Fission Explosive Weapons".) Years ago, when the BGRR was in operation at Brookhaven, the AEC was always pleased to learn that one of the reactor’s fuel elements had sprung a leak, for this was the only time that the BGRR fuel was removed from the reactor for reprocessing. Leaking fuel meant high grade plutonium for the AEC'S weapons program.

The Brookhaven Graphite Research Reactor

The BGRR consisted of a 25 foot cube of graphite, penetrated by a square, 37 x 37 array of 1368 three inch diameter air channels that contained the fuel assembles.* For efficiency in cooling the fuel, the graphite cube was split in the middle, and the two halves were separated by a 7 cm air gap. Cool air entered the reactor via this gap, passed through the air channels in both directions to the opposite surfaces of the reactor, and was then exhausted via fans to a 320 foot stack. By introducing the air at the center of the reactor, the pumping power required to move the air was reduced by a factor of eight. This feature of the BGRR was one of the principal design improvements over the X-10 reactor.

The air left the reactor at a temperature of up to 220°C, depending on the reactor power level. Since it is difficult to pump heated, low density air, the air leaving the reactor was passed through a cooler, where its temperature was reduced about a hundred centigrade degrees and its density increased. This saved on the size and operating costs of the fans.

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*The central channel contained a removable plug for experimental purposes. The number of channels was therefore 1368, not 1369.

The fuel for the BGRR was in the form of cylindrical uranium slugs 1.1 inches in diameter and 4 inches long. These slugs were loaded into hollow aluminum cartridges, 33 to a cartridge, to make the fuel assemblies. The cartridges had six aluminum fins running their full length that supported the fuel in the center of the air channels and increased the heat transfer area from the fuel to the air. One fuel assembly was used per air channel on either side Of the central air gap.

It was not necessary, however, to load all 1368 fuel channels in order to operate the reactor. The BGRR actually went critical with only about 870 loaded channels. The other channels were available to provide additional reactivity when neutron-absorbing experiments were introduced into the core.

Control of the BGRR was accomplished by the motion of horizontal control rods that entered the reactor from two adjacent corners. Supplementary emergency shutdown control could be obtained by the mechanical dumping of boron shot into holes provided for this purpose at the top of the reactor. The BGRR was equipped with an array of radiation detectors and system monitoring devices that provided operating data to a central control room.

The BGRR was housed in a large and attractive brick

building that also contained a number of offices, laboratories and seminar rooms. Since the BGRR was built primarily for research, heavy platforms were erected at several levels a cross the face of the reactor to supper t experiment a J. equipment. The overall cost of the BGRR facility was $25.5 million when it was built in 1948. Of that total, only $16.7 million was attributed to the reactor and reactor-related equipment.

A tabulation of the principal characteristics of the BGRR is given in Annex B.

A Simplified BGRR for Plutonium Production

It is not necessary to duplicate the BGRR in detail in order to produce plutonium at the same rate as it was produced in that reactor. Simplifications in the BGRR design would permit the building of a plutonium production reactor that would be cheap and reasonably reliable, and a reactor whose engineering would require the talents of only a small cadre of conventionally trained engineers. The procurement or fabrication of certain key components would be the most difficult problems that a small and/or developing nation would have to solve. These components are as follows:

Fuel. The order of 75 tons of natural uranium metal would be needed to fuel the reactor. The actual amount

of fuel would depend on the design of the reactor and the nature of the materials used to build it. Refined uranium directly suitable for reactor fuel apparently is available only from highly industrialized nations, where it is a controlled substance and not easily obtained on the open market. It cannot be exported from the United States, for example, without a license from the nuclear Regulatory Commission.

Nevertheless, a great many nations in the world possess indigenous sources of uranium ore. A table of 1975 estimates of non-U.S. uranium resources is given in Annex C. As seen in the table, nations such as Algeria and Argentina have estimated resources in excess of 30,000 tons of U_3O_8 recoverable at up to $30 *per* pound. Only the order of 100 tons of U_3O_8 is needed to obtain 75 tons of uranium metal.

The processing of uranium ore and its reduction to metallic uranium is not a difficult undertaking for a trained metallurgist. The necessary directions are in the open literature. It would require learning experience for a metallurgist who was a novice in uranium metallurgy. The problem would be much simplified if the nation in question were already a producer of U_3O_8. In any event, a well-trained metallurgist should be capable of designing and setting up a small uranium mill in 12 to

18 months which would produce 75 tons of satisfactory uranium metal in another year. The required equipment and supplies are generally available on the world market.

The cost of producing 75 tons of uranium metal is difficult to estimate, since labor, raw material, and capital costs vary so widely from nation to nation. There is no market in natural uranium in the United States at the present time. The Federal Register price of natural uranium hexafluoride is $25.39 per kilogram. The cost of uranium metal in this country is therefore about $25 per kilogram, which is not a free market price. U_3O_8 for future delivery is now being quoted as high as $40 per pound, which would give the uranium a value of over $100 per kilogram excluding processing costs. Using the nominal value of $25 per kilogram, the total cost of 75 tons of uranium comes to about $1.7 million.

Fuel Assemblies. The fabrication of fuel cartridges similar to those used in the BGRR, with their six aluminum fins running the length of each cartridge, might well pose a serious manufacturing problem to a small and/or developing nation. However, the fins are not entirely necessary for the operation of the reactor. A satisfactory and far simpler fuel assembly could be made by merely inserting uranium metal slugs into a hollow

aluminum tube sealed at both ends. These tubes could then simply be placed along the bottom of the air channels in direct contact with the graphite, a procedure followed in the x-10 reactor, or supported in the center of the channels on suitably machined pieces of graphite (which is easily machined), as was done in the British Windscale plutonium production reactor. The use of this type of fuel assembly would require modifications in the rate Of air flow through the reactor, the operating temperature of the fuel, or the reactor power level from the values of these parameters in the BGRR. The necessary adjustments could easily be determined however. The fabrication of the fuel assemblies would require about 6 months, starting with raw uranium metal.

Graphite. The graphite used in nuclear reactors must be of high purity. In particular, the concentration of the impurity boron must be as low as possible. The procurement of reactor-grade graphite was one of the first problems that had to be solved in the Manhattan Project. Although graphite occurs abundantly in nature, all commercial graphite is manufactured artificially from petroleum coke or coal tar pitch.

Graphite of the type used in the BGRR is currently available from a number of companies here and abroad, although the Department of Commerce licenses the export

of reactor grade graphite from the United States. One U.S. manufacturer recently entertained inquiries from Argentina, Brazil, and the U.S.S.R.

The Union Carbide Corporation sells reactor grade graphite for approximately $2 per pound. If the full 700 tons of graphite required to duplicate the BGRR were purchased from this company, the total cost would be $2.8 million.

However, as a already noted, a production reactor does not have to be as large as the BGRR. Instead of building a 25 ft cube, a somewhat smaller cube, say 21 ft on a side, would probably do just as well. The total amount of graphite required in this case could be as little as 415 tons and cost $1.7 million.

It should be mentioned that the processes for manufacturing reactor-grade graphite and electrode graphite are essentially the same. Facilities used for producing electrode graphite can easily be converted to the production of reactor-grade graphite. To obtain reactor-grade graphite it is most important to start with clean raw materials and to use somewhat higher temperatures. Electrode graphite manufacturing plants are located throughout the world. Union Carbide Corporation, to name but one organization, has subsidiaries manufacturing

electrode graphite in Brazil, Canada, Italy, Japan, Mexico, Puerto Rico, South Africa, Spain, and Sweden.

Graphite is easily machined. Its sizing and fabrication for use in a reactor presents no problems.

Air-Moving Equipment. Blowers of a conventional type are suitable for moving the air through a BGRR system. This equipment is readily available throughout the world. If purchased from American manufacturers, the fans and motors required to provide a flow of 300,000 cubic feet per minute would cost about $180,000 at today's prices. The associated ducting, and intake and exhaust structures would present problems. However, all necessary materials are available and could be fitted or fabricated with patience and skill.

Controls. The control of a natural uranium graphite reactor is extremely simple. There is very little excess reactivity in such a reactor so that whatever transients do occur in the reactor have long periods and are easily controlled. The control rods and their drives need not have the short response times required Of other types of reactors, e.g., water-cooled power reactors. The rods and drives could be fabricated from materials on the open market.

Instrumentation. The elaborate instrumentation found in American reactors would not be necessary for a small production reactor. A few neutron and y-ray detectors, a large variety of which can be purchased in many different countries, would suffice for the reactor. Monitors for air, graphite, and fuel temperatures are equally available.

Balance of Plant. As noted earlier, the BGRR reactor building was a well-built and attractive structure. The building for a production reactor need not be so ambitious. A simple industrial structure, steel-framed with corrugated siding could be built at no more than $3 per ft^3. A modest cubical building 55 ft on a side would then cost about $0.5 million. This is the cost if built in the United States. Overseas costs could well be much **less.**

The floor of the building would have to support about 5000 tons over an area of 2000 ft^2, for a loading on the order of 2 tons per ft^2. This is not an especially large floor loading and could be satisfied with a slab of reinforced concrete between 2 and 3 feet thick. At $100 per cubic yard, a square slab 55 ft on a side could be built for less than $35,000, U.S. prices. Presumably a deep water pool would have to be added along one side of the reactor to receive and store spent fuel until it could be processed for plutonium recovery.

Overall Costs. Estimated costs of the principal materials and structures required for a small production react or are given in the following table. These costs a r e based. on current U.S. prices, and as such they ma y have only the roughest applicability to another nation.

Table 1

Costs of Production Reactor Components

1 *tern*	Approximate Cost ($ million)
uranium	1.7
graphite	2.8
air equipment and ducts	0.5
contro1	0.2
instrumentation	0.2
building and foundation	0.6
Total	6.0

Table 1 does not include the labor costs associated with fabricating the fuel assemblies from the raw uranium meta1, Constructing the reactor within the building, connecting the ducts and air-moving equipment, and introducing the control and monitoring systems. Such costs are difficult to estimate since the cost of labor varies so widely from country to country. If 100 workers (not producing uranium

or erecting the building - this labor is included in the components costs) worked for 3 years at $10,000 per year, their total wages would amount to $3 million. Using this as a rough estimate, the reactor could be built for about $10 million - probably correct within a factor of 2.

Personnel Requirements. As pointed out repeatedly in this report, it is not necessary to design the reactor from scratch. All of the essential design parameters are in the open literature. High-level research and development personnel are not required. Onlyy a handful of professional e ngineers would suffice to design and oversee the construction of the facility. The following is a list of mininum professional personnel requirements.

Table 2

Professional Engineering Requirements

Type Of Engineer	Number	Utilization
civil-structural	1	structures, reactor building
electrical	1	control, instrumentation, circuitry
mechanical	2	heat transfer, mechanical devices
metallurgist	1	uranium production
nuclear	3	design theory, nuclear measurements, reactor heat transfer

Time Schedule. In any major project, the proper scheduling of design, procurement, and construction activities permits the simultaneous accomplishment of the required tasks. In the case of the reactor under discussion, the reactor plant parameters could be finalized and purchase orders placed while the uranium mill is being prepared. The reactor could then be erected a t the same time as the fuel assemblies are being fabricated. This phase of the project would probably take about 2 or 3 years, depending on the availability and skill of the work force. The reactor could be r e ad y for production operation 4 years from the beginning of the project.

This is probably an overestimate of the time required for the project. The X-10 reactor in Oak Ridge went into operation in November 1943, less than one year after the world's first reactor went critical in December 1942, and it was opera ted a t almost 2 MW in nay 1944. The entire BGRR project, which was not a military project, took only about 3 years.

In any case, sufficient plutonium for at least one bomb would be present in the reactor fuel one year later. A simplified scheduling diagram is shown on the next page.

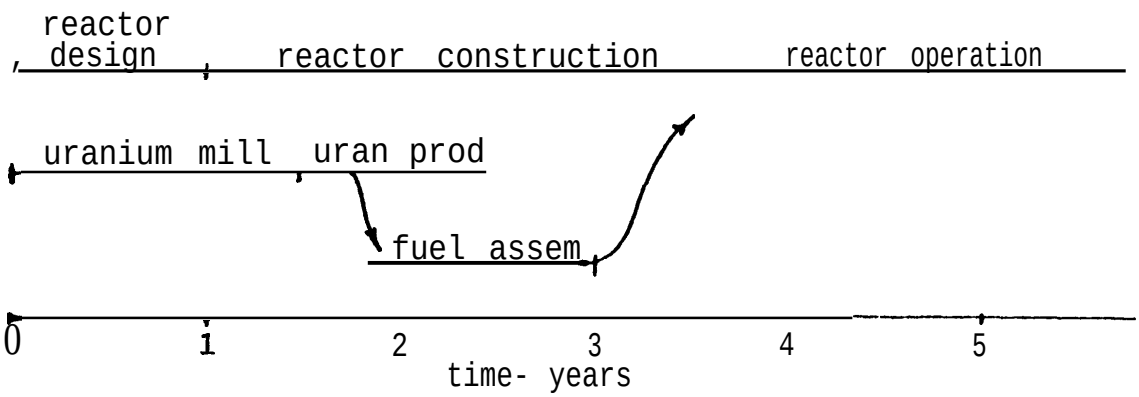

Figure 1. Schedule for design, construction, and operation of simplified BGRR.

IV RECOVERY OF PLUTONIUM FROM REACTOR FUEL

If it is desired to fabricate weapons as quickly as possible, then the fuel from the production reactor would probably be removed for reprocessing after it had been in the reactor for a period Of approximately one year. The concentration of plutonium would then be about 9 kilograms in 75 tons of fuel or about 120 grams *per* ton. The problems associated with extracting this plutonium from the fuel and preparing it for fabrication in a weapon are the subject of the present section.

These problems are not insurmountable, even for a small and/or developing nation. Indeed, such a nation could build a small reprocessing plant and recover essentially all of the plutonium-239 produced in a BGRR-type reactor. The final step of preparing this material for a weapon can also be readily accomplished, as has been amply discussed in the literature.

Some Problems in Fuel Reprocessing

In any case, a plutonium recovery plant must be designed and operated with some care. The raw fuel, when it is first discharged from the reactor, is highly radioactive, largely due to the activity of the fission products. Even if the fuel is allowed to cool for a nominal period of 120 days, during which time the activity decays by a factor of 100 or more, the total radioactivity is still about 45,000 curies per ton or 0.05 curies per gram of fuel. This means

that the chemical processing of the fuel must be carried out remotely, in a shielded cell, at least up to the point where the fission products are removed.

It should be noted, however, that the radioactivity of the BGRR fuel is much smaller than that Of a typical power reactor. The activity of power reactor fuel after a cooling-off period of 120 days runs between 2 and 3 million curies per ton, a factor of about 50 times higher than BGRR fuel. Considerably more precautions must therefore be taken in reprocessing power reactor fuel than fuel from a BGRR.

Nevertheless, the chemical methods described below provide almost complete separation of the fission product activity from the plutonium and the uranium remaining in the fuel. It is a remarkable fact that where these methods are used to recover the uranium as well as the plutonium, the activity of the recovered uranium is no greater than that of ordinary, natural uranium, which can safely be held in the bare hands.

The separated plutonium is also free of fission products and it is only mildly radioactive itself, so that it too could be handled like uranium were it not for the possibility of inhaling plutonium-bearing particles. Such airborne particles are extremely dangerous. It is approved practice, therefore, at least in the United States, for all manipulations of plutonium to" be carried out in a protected atmosphere. While such an elaborate precaution is not entirely necessary, as

indicated below, it is not difficult to arrange.

Finally, there is the danger of an accidental criticality, that is, the possibility that a critical mass of plutonium may accidentally be assembled. Only a few hundred grams of plutonium can become critical in the proper liquid environment. However, the methods for calculating critical concentrations are given in all nuclear engineering textbooks and these concentrations are widely tabulated (see especially Wick in the References). Procedures for avoiding accidental criticalities can easily be adopted.

Plutonium Recovery Processes

Several processes have been developed over the years to remove the fission products and recover the plutonium and uranium from irradiated fuel. These processes are thoroughly described in journals, textbooks, and in other open literature. The first to be perfected was the so-called bismuth phosphate process, which was the source of plutonium at the beginning of the U.S. nuclear weapons program. This process was later replaced by a solvent extraction process, first using the chemical methyl isobutyl ketone as solvent - this was the so-called Redox process - and somewhat later with the solvent n-tributyl phosphate (TBP), which is the basis of the Purex process. So far as is known, virtually all reprocessing plants that have been built in the world

since the 1950's are based on the Purex process.

Solvent extraction processes rely on the following experimental facts. Uranium and plutonium can exist in a number of valence (oxidation) states, and because of differences in their oxidation and reduction potentials it is possible to oxidize or reduce one of these elements without disturbing the other. Furthermore, compounds of these elements in different states have different solubilities in organic solvents. For instance, in their 4^+ and 6^+ states the nitrates of both uranium and plutonium are soluble in certain solvents, while in the 3^+ state these compounds are virtually insoluble in these same solvents.

Solvent extraction therefore involves three critical steps: (1) separating the uranium and plutonium from the fission products by extracting the first two into the appropriate solvent, leaving the latter in aqueous solution; (2) reducing the oxidation state of the plutonium to 3^+ so that it is no longer soluble in the solvent; and (3) back-extracting the plutonium into aqueous solution.

A simplified flow diagram for the Purex process is shown in Figure 2. The batch of fuel to be processed is first dissolved in a concentrated solution of nitric acid. The fission product gases, especially the noble

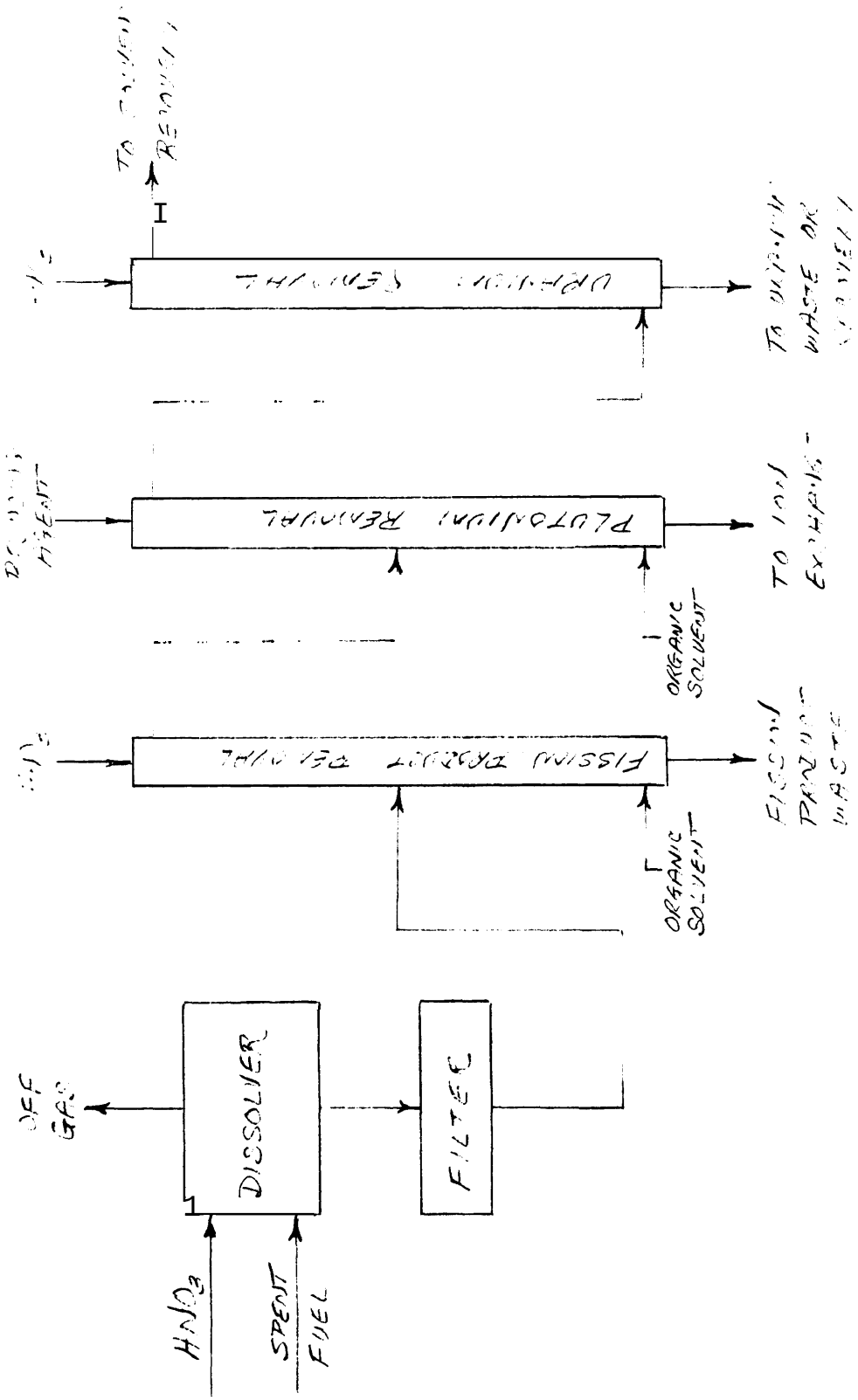

Figure 1. Simplified flow diagram for Purex process.

gases, that had been trapped in the fuel, come out of solution at this point. The release of these gases is the major source of radioactive effluent from a reprocessing plant. The aqueous solution of uranium, plutonium, and fission products, after passing through a filter to remove undissolved remnants of the fuel assemblies, then enters at the middle of the first extraction column. As the organic solvent, TBP diluted in kerosene, flows up the column, it absorbs the uranium and plutonium out of the solution. At the same time, more nitric acid enters from the top of the column to scrub the rising solvent of any fission products it may have picked up. The organic solution which leaves the top of the column contains essentially all of the uranium and plutonium and a trace of fission products, whereas the aqueous solution at the bottom has most of the fission products and very little uranium and plutonium.

The Organic solution passes next into a second column where it counterflows against a dilute solution of chemical reducing agent (a ferrous compound is often used) which reduces the plutonium to the 3^+ state, while leaving the uranium in the 6^+ state. Since the plutonium is now no longer soluble in the TBP, it passes into the aqueous solution before it leaves the column.

The uranium is stripped from the organic solvent in a third column, where the uranium passes into a counter-flowing stream of dilute nitric acid. The solvent leaving the top of the column, from which most of the plutonium, uranium, and fission products have now been removed, is piped to a recovery plant for purification and reuse. The uranium exits the column in aqueous solution.

At this point, the designs of fuel reprocessing plants tend to diverge. If the uranium is enriched in uranium-235, as it is in all American power reactor fuel, then the uranium solution is passed through additional cycles of the Purex process for the purpose of reclaiming the uranium in a highly purified state. With the natural uranium fuel of the BGRR, it is questionable whether recovery of the uranium makes sense, because the spent fuel is somewhat depleted in uranium-235. Whether or not the uranium would be recovered would depend on how long the fuel had been in the reactor and the extent and reliability of the uranium supplies available.

The plutonium solution can either be put through further Purex cycles or, what is preferable, the plutonium can be purified and concentrated through the use of the process of ion exchange. This process involves passing the solution into an ion exchange resin and then

eluting the plutonium with dilute nitric acid. The concentration of the purified Plutonium can then be increased by partially evaporating the solution, care being taken not to approach criticality conditions. This is the usual form of the plutonium output from a fuel reprocessing plant - a highly purified solution of plutonium nitrate.

It is not a difficult problem to reduce the plutonium nitrate solution to a form for making nuclear weapons. Both metallic plutonium and plutonium oxide can be used in a weapon, although the metal is preferable. To obtain the oxide, sodium oxalate, a common chemical, is added to the nitrate solution. This forms plutonium oxalate which is insoluble and precipitates from the solution. The plutonium oxalate, separated from the solution by filtration, is then heated in an oven which yields the oxide PuO_2.

To produce metallic plutonium, the oxide is heated in the presence of hydrogen fluoride and oxygen which gives plutonium tetrafluoride. This is then reduced by calcium to yield the metal. The procedures for producing the metal and fabricating it into desired forms are fully described in the references (see especially Wick).

A Small Plutonium Recovery Plant

It is clear from the foregoing remarks that the chemical engineering required for the recovery of plutonium from spent uranium fuel is relatively simple. The facts, mentioned earlier, that the fuel is radioactive, that plutonium is some forms is highly toxic and capable of going critical leads to some, but not insurmountable problems in the design of a recovery plant.

In any event, designs of such plants can be found in the open literature. For example, the plans and specifications for the Allied General Nuclear Services (AGNS) plant in Barnwell, South Carolina, have been widely distributed to the public in connection with the licensing of this plant and are available in NRC Public Document Rooms.* Furthermore, they can also be purchased

*All the plans and specifications for the AGNS plant have been made public except for the details of three devices: the electrochemical plutonium purifiers, the fuel dissolvers, and the mechanical shear. These plans were retained by the AGNS designers as company confidential and provided to the NRC as black box submittals. Nothing about this plant has been classified on the grounds of national security.

from the National Technical Information Service. AGNS is a large plant with a through capacity of 5 tons of fuel per day. Considerable scaling down of this plant would be necessary for the purpose of reprocessing BGRR fuel.

The Phillips Plant. Plans and specifications for a more appropriate, smaller plant are also available, however. In the late 1950's the Phillips Petroleum Company undertook a feasibility study of a small reprocessing plant designed to handle spent fuel from Commonwealth Edison's Dresden-1 plant, then scheduled for operation in 1960. Phillips issued a report on this study in 1961 (see References), and it was later discussed in an article appearing in Nucleonics Magazine. Although some chemical/nuclear engineers have expressed skepticism about the workability of the Phillips plant, because of its compact design and high degree of automation, it nevertheless can be viewed as an excellent starting point for the design of a reprocessing facility in a small and/or developing nation.

The Phillips report contains detailed drawings of every component of this plant. One of the striking features of the plant is its small size. With the exception of storage areas for raw materials and radioactive wastes, the whole plant is enclosed by a 65 ft x 65 ft building of standard construction. The main process

equipment is so small - for instance, the first extraction column is a pipe only 2 1/2 inches in diameter and 12 feet long - that all this equipment can be fitted into a single underground cell 12 ft square. The tail end of the plutonium recovery is carried out in a **simply-constructed** hood 3 1/2 ft wide, 12 ft long, and 12 ft high which contains three ion exchange columns, several small holding tanks, and an area for loading and weighing the product.

The plutonium output from this plant is in the form of plutonium nitrate solution. No provision is made for converting the nitrate to metallic plutonium, since this was not the purpose of the Phillips plant. The plant was designed primarily to recover enriched uranium from the fuel and separate out the fission products for disposal. Equipment to produce the metal would have to be added.

Simplifying the Phillips Plant. A number of simplifications in the Phillips plant are possible when the plant is designed for the sole purpose of recovering plutonium from BGRR fuel. In particular, the so-called head end of the plant, that portion of the plant where the fuel is dissolved into solution, need not be as complicated as in the Phillips plant. Head-end problems, according to the Phillips report, were the most formidable in designing that plant. This is because the

Dresden fuel consists of bundles Of fuel rods, each rod being a hollow zircaloy tube filled with uranium dioxide pellets. The pellets fit so tightly in the tubes that they do not fall out on their own when the tube is opened and turned upside down. It was necessary, therefore, to design an elaborate mechanical/chemical procedure for dissolving the uranium - a procedure, incidentally, that is similar to that used in the AGNS plant.

Head-end preparation of BGRR fuel is much less complicated. Since the fuel will be removed so much sooner, in terms of fuel burnup, from the BGRR than it is from Dresden, the uranium will not have had an opportunity to swell within its aluminum cladding. The uranium slugs can simply be dumped (remotely) into the dissolving tank.

As noted earlier, when the fuel dissolves in nitric acid, radioactive fission product gases which had been trapped in the fuel are released and bubble to the top of the dissolving tank. In the Phillips plant, it was proposed to separate out the rare gases and store these permanently underground. With the BGRR fuel, however, the activity of these gases is so small that they can be exhausted directly to the atmosphere - a practice followed in all currently operating reprocessing plants. For example, the total activity of krypton-85 in a full load

of BGRR fuel which has been in the reactor for one year is only 4000 curies, which in the course of reprocessing the fuel would be released from the dissolving tank over a period of a year. This is not an excessively high release rate for this isotope.

There are other simplifications to the Phillips plant. For one thing, as already mentioned, the BGRR fuel is less radioactive by a factor of 50 than typical (e.g., Dresden) power reactor fuel. This means that the concrete shielding wherever it is called for in the Phillips plans can be reduced in thickness. Provision for the storage of fission products need not be as elaborate, since their activity is so much smaller. Finally, all of the process equipment for purifying the uranium can be omitted if the uranium is not recovered and recycled.

Availability of Materials. All of the equipment and supplies required to build and operate a plutonium recovery plant are generally available on world markets. There is no single component which is so exotic that it can only be obtained from a single source. The solvent extraction columns can either be purchased on the open market or fabricated from standard piping. So can the ion exchangers. The resins used in these columns are standard Dow-Chemical type resins that are used for water treatment and other purposes. Automatic valves, ventilation equipment,

flow meters, television monitors, are all standard. None of the necessary chemicals are out of the ordinary. The hood for purifying the plutonium would probably have to be homemade, but this is not a major undertaking. In short, many small and/or developing nations can procure the materials necessary to construct and operate a small plutonium recovery plant.

Economics. The estimated base plant cost (labor and materials) of the Phillips plant was estimated to be $2,245,200 in 1960 dollars. When fees, taxes, and startup costs were included, the total price tag came to slightly over $4 million.

This figure cannot be taken seriously, however, based on experience with reprocessing plants that have actually been built. The General Electric plant in Morris, Illinois, a one ton throughput per day plant, was estimated at $17 million. The cost of the completed plant was $64 million. When it was found that the plant did not work, another $120 million was estimated to be required to put it in order. The 5 ton per day AGNS plant was originally costed out at $70 million. The actual cost (with an output of plutonium nitrate, as planned) was $200 million, and additions (e.g., nitrate to oxide conversion facility and waste solidification facility) that may be required because of new licensing regulations may add $300 or $400 million to the price.

Thus, it is exceedingly difficult to estimate the cost of a reprocessing plant. It is interesting to note, however, that in the breakdown of costs given in the Phillips report, the major cost of that plant was in the concrete (and its pouring), which was present in abundance because of the high activity of the Dresden fuel. This fact has been confirmed by officials responsible for the design of the AGNS plant - concrete is the nest expensive single item in the plant. Since the BGRR processing plant would have so much less concrete, the cost would be significantly reduced. The other simplifying; features of the plant described earlier also lead to reductions in plant cost.

It would appear, without making a detailed cost analysis, that a plutonium recovery plant of the type discussed in the present report could be built in the United States for a cost of well under $25 million, 1977 dollars. Cost in other countries would vary and conceivable could be much less. However, whether the actual cost turned out to be $25 million or twice that amount (there is no chance it would be ten times this amount - that would be the cost of AGNS, the biggest plant in the world) the fact is that this is a relatively low figure, even when combined with the cost of the reactor, compared to the usual military budget of most nations.

Personnel Requirements. As in the construction of the BGRR described earlier, high-level research and development personnel are not required to build a plutonium recovery plant, since what is necessary is largely a matter of following and/or modifying established designs. Many of the same technical personnel involved in the reactor project could be utilized for the plutonium plant. This would make good sense, because the plant would necessarily be located adjacent to the reactor, and would undoubtedly be built during the same time frame. The following is a list of minimum professional personnel requirements.

Table 3

Professional Engineering Requirements

Type of Engineer	Number	Utilization
chemical	2	process design, construction
civil-structural	1	structures
electrical	1	control, instrumentation circuitry
mechanical	1	mechanical devices
metallurgist	1	plutonium preparation
nuclear	1	shielding, criticality

V URANIUM ENRICHMENT **BY GAS CENTRIFUGES**

A standard method for separating particles of different masses is by centrifuging. This procedure has been used routinely for decades in biology and medicine to fractionate blood and other biological materials. The material to be separated is placed in a suitable vessel and this is rotated at great speed. The rotation creates what, in effect, is a strong gravitational field, and, as a result, the heavier particles tend to move to the periphery of the vessel while the lighter ones remain near the center.

The fact that gravitational or centrifugal fields could be used to separate isotopes was first pointed out by Lindemann and Aston in 1919. It was twenty years, however, before such separation was successfully obtained. This was achieved by J. W. Beams and his coworkers at the University of Virginia, using a specially-designed centrifuge

The possibility of obtaining highly enriched uranium for nuclear weapons by centrifuging was recognized by Beams immediately after the discovery of fission. Indeed, according to the Smyth Report on the Manhattan Project, "for a long time in the early days of **the project, the gaseous** diffusion method and the centrifuge method were

considered the two separation methods most likely to succeed with uranium."

The first attempt **by** Beams to separate the isotopes of uranium, which was held up until late in 1940 because of the unavailability of uranium hexafluoride (UF_6), was an immediate success. Subsequently, it was decided to build a small pilot plant at the Bayway, New Jersey, laboratory of the Standard Oil Development Company using 24 centrifuges designed and built by the Westinghouse Electric Company. However, only two machines were actually delivered to Bayway before the entire centrifuge project was scrapped at the end of January 1944. Nevertheless, one of these machines was operated successfully for a period of 99 days, and it yielded the degree of separation that had been predicted theoretically.

Figure 3 shows a diagram of the Westinghouse short-bowl centrifuge. The bowl or rotor was 42 inches long and 7.2 inches in diameter and rotated at a rate of 28,200 rpm. This was above the critical speed for the vibration of the rotor. A model of a machine with a 132 inch rotor was also built and tested in 1943.

During the decade following World War II, the centrifuge method for separating isotopes was largely

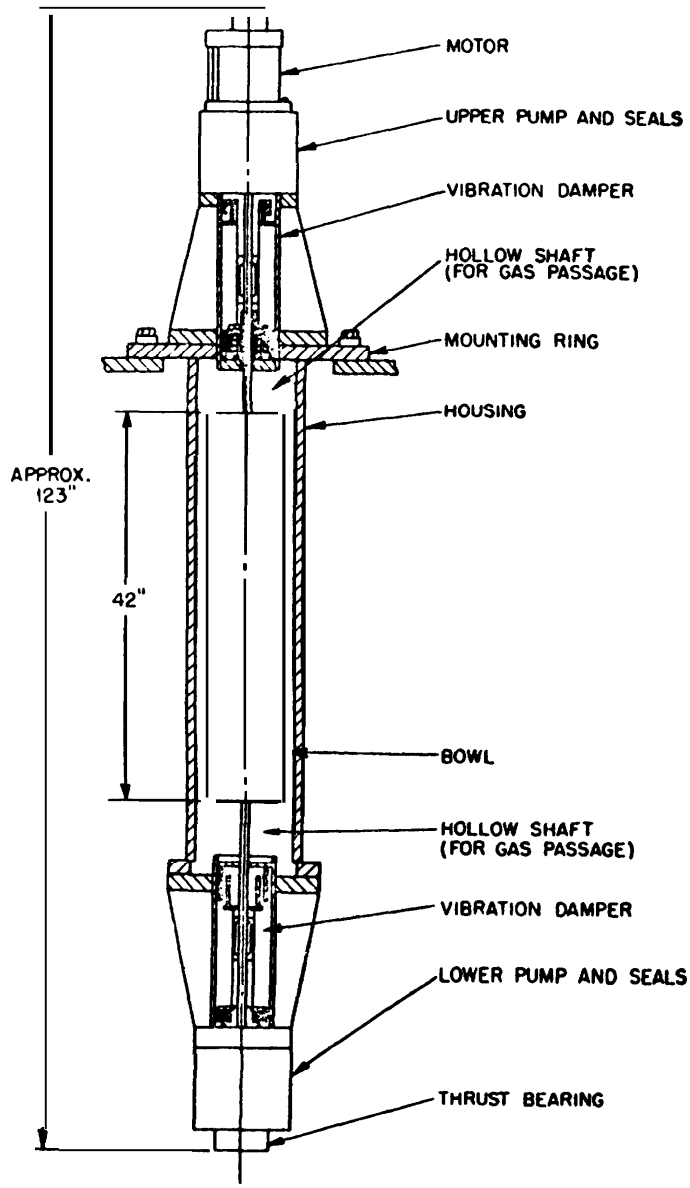

Figure 3. Manhattan Project centrifuge. (From J. W. Beams, see References.)

forgotten in the United States, except for a small project at the University of Virginia. However, work on centrifuges was continued in Germany and also in the Soviet Union. The Soviet team included a number of German scientists that had been captured at the end of the war. Prominent among this group was G. Zippe, who made a number of significant improvements on centrifuge design. Shortly after Zippe had been repatriated from the Soviet Union, he was invited to the University of Virginia to repeat the experiments he had carried out with the Soviets. He began work on a new centrifuge in August 1958 and it was completed in June 1960, when he was repatriated for the second time.

The Zippe machine has evidently been the basis for many of the recent developments in centrifuge technology. A schematic drawing Of the Zippe short bowl centrifuge is shown in Figure 4. The centrifuge rotor, 0, is 3 inches in diameter and 13 inches long. It spins on a thin, flexible steel needle, which is centered in a depression in a hard metal plate, P, whose lateral motion is damped in oil. Rotational motive power is obtained from the electric motor, M, the armature of which is the steel plate, N, fastened rigidly to the bottom of the rotor. The upper bearing, B, consists of a hollow cylindrical permanent magnet that attracts a

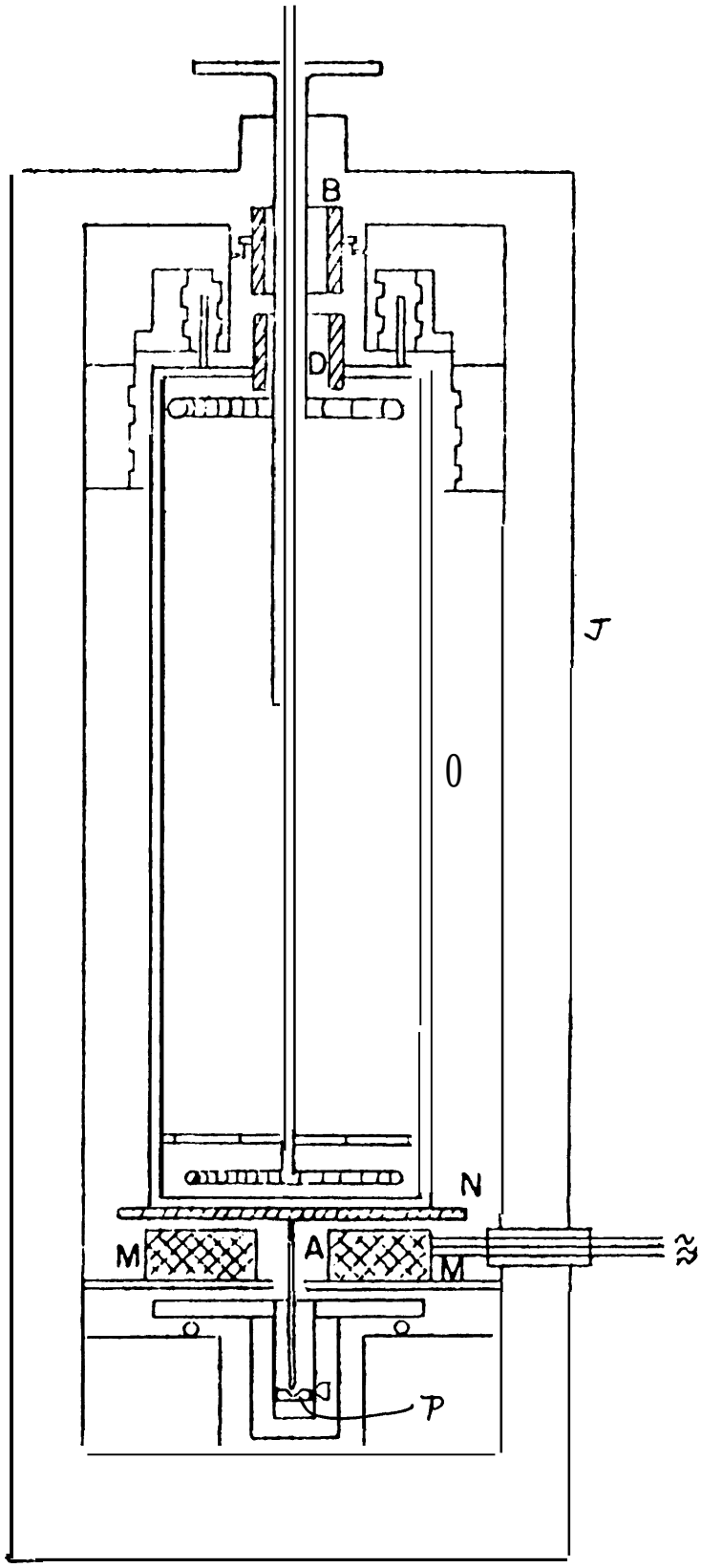

Figure 4. Zippe short bowl centrifuge.

(From J.W. Beams, see References.)

s tee 1 tube, D, mounted on the rotor. In this way, there is no mechanical contact between the axis of the rotor and the frame. The volume within the protective jacket, J, is evacuated so that the rotor spins in a vacuum. Even this small machine, which operated at subcritical speeds, was capable of producing separative work (see Annex D) at a rate of 0.45 kg per year.

With the successful demonstrating of the Zippe machine, the U.S. Atomic Energy Commission recognized that the centrifuge might possibly be developed into an economic method of separating:: the isotopes of uranium. Furthermore, since centrifuges apparently could be fabricated with relatively little difficulty and consumed very little power, the possibility existed that centrifuging might provide a mechanism for many small and/or developing nations to acquire a nuclear weapons capability. Accordingly, in 1960 the AEC declared that all work on centrifuges, which was unclassified at that time, would henceforth be classified.

Thereupon the AEC evidently undertook an accelerated program to develop the centrifuge for isotope separation.

Today the centrifuge process has reached a high level of sophistication, both in this country and abroad. According to authorities in the field, centrifuging is unquestionably cheaper than any other developed (this excludes laser separation) method of enriching uranium. An Anglo-Dutch-German enrichment group, Urenco, has successfully demonstrated the first cascades of two small centrifuge plants each with a planned capacity of about 200,000 kg SWU per year at Capenhurst, England, and Almelo, Holland. A small pilot plant is in operation, or about to go into operation, in Oak Ridge. One American firm has proposed building a major uranium enrichment plant to provide fuel for the nation's nuclear power plants.

Principles of Centrifuge Separation

In an isotope separation plant the basic unit that separates the isotopes is called a separating unit. In a gaseous diffusion plant this is a single diffusion barrier; in a centrifuge plant it is a single centrifuge machine. To provide the necessary material flow through a plant, Several Separating units are usually connected in parallel, that is, side by side. Such a group of parallel-connected units is referred to as a stage.

Since only a certain amount of separation can be obtained from a single stage, it is always necessary to connect a number of stages in ***series.*** An arrangement of

this type is called a cascade.

The degree of separation which is possible in one separating unit or one stage is determined by the separation constant α. Clearly, the larger the value of α, the shorter the cascade can be. In the gaseous diffusion process, a is given by the square root of the ratio of the masses of the process gases, $^{238}UF_6$ and $^{235}UF_6$, and has the value 1.00429. Since this number is only slightly greater than unity, a great many (about 3000) stages are required in a gaseous diffusion cascade to produce weapons grade uranium, about 90 percent ^{235}U. By contrast, in the centrifuge method for isotope separation, a is determined by the difference in mass between the heavy ($^{238}UF_6$) and light ($^{235}UF_6$) component, and increases with the length and the peripheral speed of the centrifuge rotor. It is possible, therefore, by operating a centrifuge with a long rotor at a sufficiently high speed to obtain values of a which are substantially larger than for the corresponding case with the diffusion process. The cascade for a separation plant based on the centrifuge process is then shorter than for the equivalent plant using gaseous diffusion. With a separation factor of 2, for example, apparently not an unreasonable value, only about 20 stages would be required to produce 90 percent uranium. This short cascade is one of the attractive features of isotope separation by centrifuge.

The rate at which a given separative unit or a cascade is actually capable of separating isotopes is measured in terms of separative work units, SWU, per unit time. For a single centrifuge, it has been shown that this rate is proportional to the length of the centrifuge and increases rapidly with its peripheral speed. To obtain large amounts of separative work per machine, it is therefore desirable to make the rotors of the machines as long as possible and operate at exceedingly high speed, which, as already noted, also reduces the length of the cascade.

However, this immediately leads to a difficult problem. As the speed of a rotor is increased, the rotor passes through a succession of vibration resonances which place the structure under great stress. At these so-called critical speeds the rotor has a tendency to fly apart, before the centrifuge has had an opportunity to reach its operating speed.

Evidently, the centrifuges used in the European pilot plants do not operate at supercritical speeds. Each is capable of producing somewhere in the neighborhood of 2 to 5 kg of SWU per year. In an unclassified remark, Dixie Lee Ray, former chairman of the U.S. Atomic Energy Commission, was reported to have said that 10,000 centrifuges of American design would do the same job as 100,000

European centrifuges. Since no exotic materials development could possibly account for an improvement by a factor of 10 in the performance of a subcritical centrifuge, it must be concluded that U.S. engineers have solved the problem of substantial supercritical operation. (It may be observed that the early machines of the Manhattan Project also operated at supercritical speeds.) If, in fact, Dr. Ray's statement is an accurate account of American centrifuge technology, then each centrifuge must be capable of producing somewhere between 20 and 50 kg of SWU per year.

As shown in Annex D, a plant with a capacity of between 2000 and 2300 kg of SWU per year, depending on tails assay, is necessary to produce 10 kg of weapons grade uranium per year. This means that a total of between 400 and 1200 centrifuges of European design would be required, depending on their individual capacities, or perhaps only 40 to 115 centrifuges of American design.

It should be pointed out that the electrical power required to operate a centrifuge separation plant is estimated to be only one-thirteenth the power for a gaseous diffusion plant. Since a diffusion plant requires an installed capacity of approximately 0.25 kW per kg of SWU per year, the corresponding centrifuge plant would need about 0.020 kW per kg of SWU per year or a total of only

46 kW for a 2300 kg SWU per year facility.

Another striking advantage of the centrifuge method, especially to a small and/or developing nation embarking on a weapons program, is that a small number of units or groups of centrifuges can be placed in operation as soon as they are built and tested. There is no necessity, as there is in the gaseous diffusion process, to wait upon the completion of an enormous facility before beginning separative operations. Production of weapons grade uranium can begin at a small level of SWU per year and gradually be increased as additional centrifuges come off the assembly line.

Problems with Centrifuge Technology

Having discussed the advantages of the **centrifuge** method over other methods of separating isotopes, it is appropriate to ask whether a small and/or developing nation can reasonably be expected to attempt to produce nuclear weapons by this method. For several reasons, it would appear doubtful that centrifuge separation would be the **process of choice** for **obtaining such weapons.**

To begin with, centrifuge separation is a highly sophisticated technology that has only recently been developed by a few of the most advanced nations in the world. Th$_e$ technical problems are formidable. The

centrifuges must spin in a vacuum at high speeds, magnetically supported at one end and on a special bearing at the other. The rotors must be fabricated from special materials of high tensile strength and the interior Of the rotors, the process vessel, must be immune to attack by uranium hexafluoride, the process gas, which is extremely corrosive, hydroscopic and dangerous to work with. Arrangements must be made to carry the processed gas into and out of each centrifuge, from stage to stage, and, of course, the entire cascade must be controlled. Finally, unless the critical speed problem is solved, a large number of machines must be used for a comparatively small output.

While the major powers have solved most or all of these problems, their technology is classified and likely to remain so. This means that a new nation that elects to pursue centrifuge separation must undertake what can be expected to be a lengthy research and development program with uncertain results. This is in marked contrast to the situation such a nation would face in producing plutonium in small reactors, in which case, as pointed out in Section III, the technology is not only unclassified, but complete facility plans are readily available. Also, since centrifuge separation technology is new, the project personnel would have to be trained

from scratch within the nation's borders, whereas nuclear reactor engineering is taught openly around the world. Lastly, the fact that a centrifuge program would take so long to produce results would deter a small and/or developing nation from beginning such a project. Ideally, nuclear weapons should be acquired over a short time span to avert detection, and with a large degree of certainty of success.

It should be added, however, that if a nation were willing to scale down its nuclear weapons program to a level where only one bomb was produced every five *or* ten years, then in this case the centrifuge method might appear attractive. Nevertheless, it would also seem extremely doubtful that such a long term program could remain secret until a militarily significant number of weapons could be produced.

ANNEX A

PLUTONIUM PRODUCTION RATES

Plutonium-239 is produced in a thermal reactor as the result of the absorption of thermal and resonance neutrons by ^{238}U. The rate of ^{239}Pu production in atoms per second in the entire reactor is given by

$$R = N_{28}\bar{\sigma}_{a28}\phi_T V + (1-p)\varepsilon\eta_{25}\bar{\sigma}_{a25}P_F\phi_T V, \quad (1)$$

where N_{28} and N_{25} are, respectively, the number of ^{238}U and ^{235}U atoms per cm^3 and $\bar{\sigma}_{a28}$ and $\bar{\sigma}_{a25}$ are their average thermal absorption cross sections; p is the resonance escape probability; ε is the fast fission factor; η_{25} is the average number of neutrons emitted by ^{235}U per neutron absorbed in that nucleus; P_F is the probability that a fission neutron will not escape from the reactor while slowing down; ϕ_T is the average thermal flux in the reactor; and V is the reactor volume. In Eq. (1), fissions in ^{239}Pu and ^{241}Pu have been ignored, since the concentrations of both these nuclides are small in a natural-uranium, graphite-moderated reactor. The first term in Eq. (1) is due to thermal neutron absorption; the second is due to resonance absorption.

The number of atoms of ^{239}Pu produced per atom of ^{235}U consumed in the reactor is called the conversion ratio

or sometimes the breeding ratio and is denoted by the symbol C. Since 235U is consumed at the rate of $N_{25}\bar{\sigma}_{a25}\phi_T V$ atoms per second, it follows that

$$C = \frac{R}{N_{25}\bar{\sigma}_{a25}\phi_T V} \quad \frac{N_{28}\bar{\sigma}_{a28}}{N_{25}\sigma_{a25}} + (1-p)\varepsilon\eta_{25}P_F. \qquad (2)$$

The values of the parameters in Eq. (2) are as follows:

$$N_{28}/N_{25} = 99.27/0.72$$

$$\bar{\sigma}_{a28}/\bar{\sigma}_{a25} = 2.70/680.8$$

$$\eta_{25} = 2.068$$

and for the Brookhaven Graphite Research Reactor,

$$p = 0.8783$$

$$\varepsilon = 1.03$$

$$P_F \approx 1.$$

Introducing these parameters into Eq. (2) gives C = 0.806. Incidentally, the first term in Eq. (2) is about twice as large as the second term, which means that for reactors of the Brookhaven type twice as much ^{239}Pu is produced by thermal neutron absorption as by resonance neutron capture.

A thermal reactor opera ting at a power level Of one megawatt (MW) consumes 1.23 grams of ^{235}U per day or 1.23 x 365.25 = 449.26 grams per year. Such a reactor produces ^{239}Pu at the rate of 449.26 x 0.806 x (239/235) = 368.27 grams per year. If the reactor operates at a power of P MW, it follows that

^{239}Pu production rate = 368.27P grams per year. (3)

Since 239Pu absorbs neutrons, it is consumed as well as produced in an operating reactor. If n_{49} is the total number of 239Pu atoms in the reactor at any time, then n_{49} is determined by the equation

$$\frac{dn_{49}}{dt} = R - n_{49}\bar{\sigma}_{a49}\phi_T. \quad (4)$$

The solution to this equation is

$$n_{49} = \frac{R}{\bar{\sigma}_{a49}\phi_T}\left(1 - e^{-\bar{\sigma}_{a49}\phi_T t}\right). \quad (5)$$

Equation (s) shows that the amount of ^{239}Pu rises with a half-life time constant of $0.693/\bar{\sigma}_{a49}\phi_T$. The value of $\bar{\sigma}_{a49}$ is 0.886 x 1011.3 = 896 barns = 8.96 x 10^{-22} cm^2. In the BGRR the maximum thermal flux was 5 x 10^{12} neutrons/cm^2-see and so the average thermal flux was approximately 5 x 10^{12}/3.88 = 1.29 X 10^{12}, where the

factor 3.88 is the maximum-to-average flux ratio for a cubical reactor. The time constant in Eq. (5) is then

$$\frac{0.693}{8.96 \times 10^{-22} \times 1.29 \times 10^{12}} = 6.00 \times 10^{8} \text{ sec} = 19.0 \text{ years.}$$

This result means that for times short compared with 19 years, the amount of ^{239}Pu in the reactor can be computed by multiplying the production rate in Eq. (3) by the length of time that the fuel is left in the reactor at the power of P MW. In the case of the Brookhaven reactor, F varied between 22 MW and 30 MW. Using the nominal value of 25 MW gives an annual production of 368.27 x 25 = 9207 grams or 9.2 kilograms of ^{239}Pu.

This plutonium is not produced uniformly throughout the reactor. Because the neutron flux is highest at the center of the reactor, the ^{239}Pu concentration is also highest in that region. The average concentration of the ^{239}Pu in the fuel is 9207/75 =123 grams per ton. Near the center, the concentration is on the order of 3.88 x 153 = 476 or about 500 grams per ton. From a practical standpoint, this is the fuel that should be withdrawn from the reactor first, and this is the concentration for which the plutonium extraction facility should be designed.

ANNEX B

PARAMETERS OF THE BROOKHAVEN GRAPHITE RESEARCH REACTOR

Power: up to 30 MW.

Neutron flux: 5×10^{12} maximum, 1.3×10^{12} average.

Fuel: natural uranium slugs 4 in. long, 1.1 in. in diameter, in finned aluminum cartridges 11 ft. long; tot a 1 uranium fully loaded 116 tons, normal loading 75-90 tons.

Fuel arrangement: 37 x 37 square lattice, 8 in. pitch.

Moderator: graphite, 700 tons.

Coolant: Air, 300,000 cubic ft per minute, exit temperature 330°F, fan power 5 MW.

Reflector: graphite, 4.5 ft.

Shielding: iron plate plus 4.25 ft. concrete.

Control: 16-2 in. square by 12.5 ft. long steel rods Containing 1.75 percent boron, in 2 banks entering horizontally from 2 corners of reactor.

Additional features: (1) fuel cartridges pressurized with helium for leak detection; (2) reactor split in middle by 7 cm gap through which air enters.

ANNEX C

FOREIGN, NON-COMMUNIST RESOURCES OF URANIUM*
(in thousands of short tons)

Country	Reasonably assured	Estimated additional	Total
	up to $15/lb. U_3O_8		
Australia	316	100	416
S and SW Africa	240	8	248
Canada	187	421	608
Niger	52	26	78
France	48	33	81
Algeria	36		36
Gabon	26	6	32
Spain	13	11	24
Argentina	12	18	30
Other	56**	26	82
Total	986	649	1635
	Up to $30/lb. U_3O_8		
Sweden	390		390
Australia	316	100	416
S and SW Africa	357	96	453
Canada	216	545	761
Spain	30	55	85
France	71	53	124
Niger	65	39	104

Country	Reasonably assured	Estimated additional	Total
Algeria	36		36
Argentina	27	51	78
Other	152***	111	263
Total	1660	1050	2710

* 1975 ERDA values

** Includes Central African Republic, Germany, India, Japan, Mexico, Portugal, Turkey, Yugoslavia, Zaire, and Brazil.

*** Includes, in addition to (**), Denmark, Finland, Italy, Korea, and the United Kingdom.

ANNEX D

SEPARATIVE WORK

The overall process of isotope separation is shown schematically in Figure D.1. Over some time period, M_F kg of uranium feed, that is, uranium to be enriched, containing ^{235}U at a concentration of x_F weight percent, enters the separating device or plant and M_p kg of product emerges with the enrichment X_p along with M_T kg of residue (tails) at the depleted enrichment x_T.

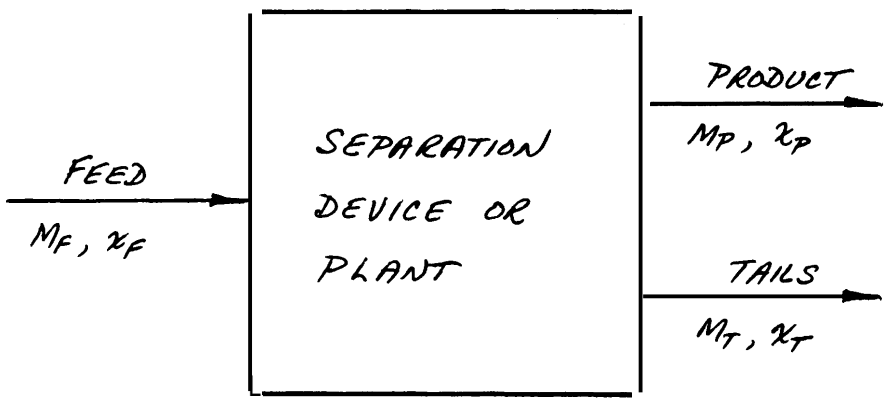

Figure D.1. Schematic representation of isotope separation.

Since the separation of isotopes requires, in effect, an unmixing of two gases, the entropy of the gases decreases in the process. As a result, work must be done on the gases by whatever device is performing the separation. This work is normally measured in Separative Work Units (SWU), which have units of mass (kg). The rate at which a device or an

entire separation plant is separating isotopes is measured in SWU per unit time, e.g., kg of SWU per year.

The separative work can also be expressed as the increase in the value of the enriched product and the depleted tails, taken together, less the value of the feed. Specifically, this is

$$SWU = M_P V(x_P) + M_T(x_T) - M_F V(x_F), \tag{1}$$

where V(x) is the value function

$$V(x) = (2x-1)\ln\left(\frac{x}{1-x}\right). \tag{2}$$

In view of the conservation of mass,

$$M_F = M_P + M_T, \tag{3}$$

Eq. (1) can also be written as

$$SWU = M_P\left[V(x_P) - V(x_T)\right] - M_F\left[V(x_F) - V(x_T)\right]. \tag{4}$$

From the conservation of ^{235}U, it follows that

$$x_F M_F = x_P M_P + x_T M_T. \tag{5}$$

Combining Eqs. (3) and (5) gives

$$M_F = \left(\frac{x_P - x_T}{x_F - x_T}\right)M_P. \tag{6}$$

Introducing Eq. (6) into Eq. (4) yields finally

$$SWU = M_P \left\{ \left[V(x_P) - V(x_T)\right] - \left(\frac{x_P - x_T}{x_F - x_T}\right) \left[V(x_F) - V(x_T)\right] \right\} \quad (7)$$

The assay or enrichment of natural uranium feed is fixed at 0.711 weight percent. According to Eq. (7), the amount of separative work required to produce M_p kg of product depends both on the enrichment of the product and on the residual enrichment of the tails.

Suppose it is desired to produce 10 kg of 90 percent uranium (90 w/o ^{235}U) at a tails assay of 0.2 w/o. Then from Eq. (2), V(0.90) = 1.758, V(0.00711) = 4.869, and V(0.002) = 6.188. Equation (7) then gives SWU = 2274 kg. On the other hand, if a tails assay of 0.3 w/o is acceptable, then 11(0.003) = 5.771 and Eq. (7) gives SWU = 2009 kg.

It should be noted from Eq. (6) that as the tails assay is increased, the amount of feed material also increases. Thus to produce 10kg of 90w/o at 0.2 w/o tails requires 1757 kg of natural uranium or about 2600 kg of UF_6. At 0.3 w/o tails the amount of UF_6 increases to 3230 kg.

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APPENDIX VI-B

LEVEL II DEDICATED FACILITIES

by

John R. Lamarsh

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Introduction

If, for military or political reasons, a nation embarking on a nuclear weapons program via dedicated plutonium production facilities must keep the existence of the program secret, then the individual components of the program - the reactor, the plutonium recovery plant, and so on - must be restricted in size and capacity. This effectively limits the reactor power level to the order of 25 megawatts (MW). While such a small reactor might be concealed, a much larger reactor could not. A small 25 MW reactor producing about 10 kg of plutonium annually is called a level I facility.

On the other hand, if the nation openly undertakes a nuclear weapons program, there are no such restrictions. Like any other military program, it is limited only by the availability of funds, personnel, and critical

materials. Facilities capable of producing about 100 kg of plutonium per year, enough for between 10 and 20 nuclear weapons, are termed level II facilities. In this report, some of the more reasonable options are considered for the construction of these types of facilities.

Magnitude of Program - Plutonium Production Rate

It is safe to assume that any dedicated plutonium production reactor would be fueled with natural uranium, since if facilities for the enriching of uranium were available, it would be more logical to base a weapons program entirely on enriched uranium rather than reactor-produced plutonium. The conversion ratios of most practical natural-uranium fueled reactors are approximately the same, namely, about 0.8. With this conversion ratio, Pu-239 is produced at a rate of o.368 kg per year per megawatt of operating power.

Some of this Pu-239 is consumed within the reactor, either in fission or by conversion to Pu-240 and Pu-241, at a rate that depends on the thermal flux in the reactor. At a flux of 10^{12} neutrons/cm^2-see the exponential time constant (mean life) for the depletion of the Pu-239 is 35.3 years; at a flux of 10^{13} it is 3.53 years. Except for reactors operating at a flux much in excess of 10^{13}

neutrons/cm^2-see the net production rate of Pu-239 can therefore be taken to be roughly 0.37 kg/MW-year.

In order to produce 100 kg of Pu-239 per year would require a reactor operating at a power of about 100/0.37 = 270 MW, provided that the reactor operated continuously throughout the year. While small reactors can, in fact, be operated continuously over long periods of time, it has been found by experience that larger reactors are ordinarily shut down the order of 30 percent of the time. This means that in order to produce 100 kg of Pu-239 per year, the reactor must actually operate at a power of almost 400 MW. This is the power level that will be assumed for level II facilities in the present report.

Reactor Options

The distinguishing features of a plutonium production reactor, once the type of fuel has been determined, are its moderator and coolant. Several different choices are possible. For a natural-uranium fueled reactor, the moderator can be either heavy water or graphite. No other practical moderating material will provide a critical system with natural uranium as fuel. The coolant, however, can be either ordinary or heavy water, or any one of a number of gases. Presumably a nation would opt to construct

that type of reactor which is the cheapest and easiest to build. As shown below, this would most likely be a graphite-moderated, water-cooled reactor.

Heavy water moderated reactors. As a moderator, heavy water is far superior to graphite. Fission neutrons slow down more rapidly in heavy water than in graphite because of its lower atomic/molecular weight, and once thermalized, the neutrons are not as readily absorbed in heavy water as in graphite because of its lower absorption cross section. A heavy water moderated reactor therefore has a higher multiplication factor than a comparable graphite moderated reactor, and, as a result, a heavy water reactor more easily goes critical - that is, a smaller amount of fuel and moderator is required than for a similarly fueled graphite reactor.

These facts notwithstanding, it does not appear likely that any small and/or developing nation would be successful, certainly at an early date, in producing plutonium in" a heavy water moderated reactor. The reason is simply that heavy water would be exceedingly difficult to obtain. There are only two major producers of heavy water in the world today - the United States and Canada, and both of these countries control its export. Under current regulations, heavy water is not exported except to

signatories to the Nonproliferation Treaty, and presumably only for the use in recognized power reactors.

With heavy water not generally available on the world market, a nation would be forced to produce it on its own. Approximately 300 kg of heavy water moderator are required per MW of reactor power. A 400 MW reactor would therefore require a total of about 120 Te of heavy water. The production of this amount of heavy water presents a formidable problem. The production of heavy water is not a simple undertaking. Wile in principle it can be made in a number of different ways, the presently universally adopted process for producing heavy water involves chemical exchange reactions between hydrogen sulfide (H_2S) and water. A gas, H_2S is both corrosive and lethal. Successful heavy water plants therefore require a high level of technical sophistication in their design and operation. Indeed, one plant built in Canada of American design simply did not work. In the opinion of experts in heavy water technology, only a nation with a major chemical industry and high-trained personnel could possibly produce the heavy water required for a level II plutonium production reactor.

For the above reasons, heavy water moderated reactors for level II plutonium production can be largely ruled out.

Graphite moderated reactors. These types of reactors were the first to be built, and they do not require a high level of technology for their design or construction. While graphite is not as good a moderator as heavy water, it is relatively cheap and readily available on the world markets. Should graphite ever become a nationally controlled substance, it can readily be produced domestically. Graphite is easily machined and structurally sound, it can be stacked to necessary heights, it maintains its dimensions, and it is essentially inert at normal temperatures.

While a small level I graphite reactor can be cooled with air in a once-through system, at the more elevated power levels of a level II reactor air is not the advisable

coolant. in order to compensate for the poorer heat transfer properties of a gas, gas-cooled reactors **are** normally opera ted at high temperatures, and at high temperatures air reacts with graphite. A more chemically inert gas, such as helium or CO_2, must therefore be used to cool graphite reactors, but these coolants create other problems. For one thing, for obvious reasons, the y can only be used in closed loops, which means that heat exchangers and secondary coolants must be used to remove the reactor heat. This is an entirely reasonable procedure for a reactor used to produce electrical power, since steam can be generated in the secondary loop, but it introduces needless complications in a plutonium production reactor. A closed primary loop requires that either the entire *core a- large structure* when the fuel is natural uranium - must be enclosed in a gas-tight pressure vessel or the individual coolant channels must be enclosed in gas-tight tubes.

Another negative feature of gas-cooled reactors of the natural uranium type is that again because of the poor heat transfer properties of gases, a significant fraction, upwards of 10 percent, of the reactor power is required to provide the necessary flow of coolant through the reactor to cool the core. Finally, with regard to

helium as a coolant, this gas has only limited availability in the market places of the world, and its use poses unique technological problems of its *own*. It should also be mentioned that any closed cycle cooling system introduces serious difficulties in the loading and unloading of fuel - difficulties that should be avoided if possible, especially in a production reactor.

In contrast to closed cycle gas cooling, once- through water cooling is simplicity itself. Water, obtained from a suitable natural source such as a river, is passed along the fuel rods, collected at the far end, and returned to the source. However, water does absorb thermal neutrons, so that the introduction of water into a thermal reactor tends to reduce the multiplication of the system. Indeed, during the Manhattan Project when the Hanford plutonium production reactors were being designed, it was not clear that a natural-uranium fueled, graphite - moderated reactor containing the amount of water necessary for cooling and constructed with graphite of uncertain purity would ever go critical. Until early in 1943, in fact, it was generally assumed that the plutonium pro- duction reactors would have to be helium cooled. Water also has other problems, especially the fact that it is highly corrosive. Special care must be taken to assure

that the proper materials are used throughout a water-cooled reactor in order to reduce corrosion to a minimum.

Small Hanford-Type Reactors

In view of the foregoing discussion, it would appear that a logical choice for a level II production facility would be a once-through, water-cooled, graphite-moderated, natural-uranium-fueled reactor. Such a reactor would be similar to the first reactors built at Hanford, Washington in the Manhattan Project. A total of **nine such reactors were built at Hanford during and subsequent to World War II. The first reactors operated at a power level of between 1800 and 2500 MW; later reactors operated at 4000 to 4400 MW.** The total power of all the Hanford reactors taken together was about 21,000 MW. At this power level, and with an average plant availability factor of 70 percent, the Hanford facility was capable of producing the order of 5000 kg Of plutonium per year. One by one, the Hanford reactors were shut down during the 1950's and 1960's as the nation’s need for additional plutonium diminished, and production shifted to the more modern heavy water reactors at Savannah River, South Carolina. Only one reactor, the so-called N Reactor, is still in operation

at Hanford, having been converted into a dual plutonium-producing and electricity-producing (860 MWe) system.

Th e first Hanford reactors, of necessity, were fueled with natural uranium. However, the excess reactivity of these reactors was inconveniently small. Early in the Hanford program, therefore, about 15 percent of the fuel was replaced with slightly enriched uranium (0.947 weight percent). Most of the excess reactivity of the Hanford reactors was required to compensate for equilibrium Xenon. The high power levels of these reactors requires a high thermal neutron flux, and this, in turn, leads to xenon reactivity levels on the order of two percent. A somewhat smaller amount of reactivity was needed because of the negative temperature coefficient. Almost no reactivity was included for burnup, since one-fifth of the fuel was removed for reprocessing every 5 to 6 weeks.

While a nominal 400 MW level II reactor would operate at only about one-fifth the power of an early Hanford reactor, the nuclear designs of the two systems would be very similar. In particular, it would be reasonable to construct the new reactor with the same fuel-coolant-moderator lattice as a Hanford reactor. The overall dimensions of the lower-power reactor would

be smaller, however, because the reactor, operating at lower neutron flux and temperature, would require less excess reactivity.

Rough calculations given in the Appendix indicate that a 400 MW Hanford-type reactor would be a cubical pile, the core of which would be about 33 ft on a side. The total amount of natural uranium in the reactor would be 387 metric tons. At a nominal cost of $25 per kilogram, this would cost about $10 million. The total amount of graphite, including the reflectors would be 2250 metric tons, and at $2 a pound the graphite would also be about $10 million.

Beyond the costs of the fuel and moderator, it is very difficult to make meaningfuel estimates of the cost of a Hanford-type reactor. Cooling water must be brought to the face of the reactor, pumped through the 2200 channels, collected, and returned to the source. This obviously involves costly problems of a plumbing nature. Mechanisms must be provided for the loading and unloading of fuel - mechanisms that must work smoothly in view of the short intervals between fuel changes. Massive shielding must be erected around the reactor which does not interfere with either the coolant piping or the fuel handling equipment. The structural framework and

foundation supporting the reactor must be designed with some care in view of the large floor loadings and the need to maintain the system motion free. Finally, the reactor must be instrumented and controlled.

It is clear that the construction of a 400 MW production reactor would be a difficult undertaking for most nations. Most nations would be far better advised to construct a number of smaller air-cooled reactors, which can be built one by one, tested and operated to prove their design. In view of the time and effort required and the risks involved to realize significant amounts of plutonium from a larger reactor project, the gradual buildup of plutonium production capacity with small reactors would seem to be a much more reasonable strategy.

ANNEX

Calculations of Small Hanford-Type Reactors

Reactor calculations can be divided into two parts: those concerned with reactor physics and those pertaining to the engineering of the system. In the actual design of a reactor there is considerable interplay between these two areas, especially in connection with any effort to optimize the design. No such optimization is attempted in the calculations which follow. They are intended merely to indicate the types of calculations which would be involved in the design of a small Hanford-type reactor.

1. The Hanford lattice.

The fuel for the early Hanford reactors was in the form Of natural uranium slugs **1.359 in. in diameter and** about 8 in. long (their exact **length is unimportant for** present purposes), which were **clad in aluminum, 0.0405 in.** thick. These clad slugs were **loaded into an aluminum** tube 0.072 in. thick that had **two supporting ribs as** shown schematically in Figure **1. These fuel elements were placed in aluminum process tubes (later replaced with zircaloy) also approximately 0.072 in. thick, which passed through the horizontal holes in the graphite. This provided an 0.086 in. thick annulus for cooling**

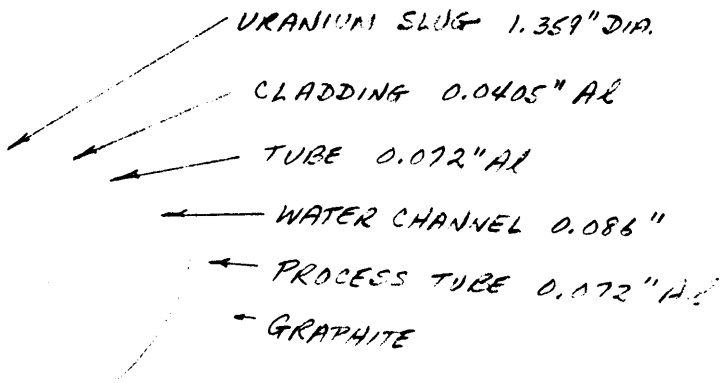

Fig. 1. Cross section of fuel, cladding, and coolant. channel of Hanford reactor.

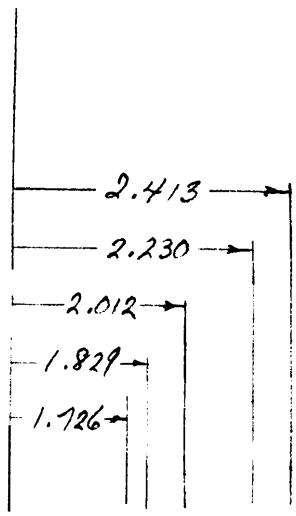

Fig. 2. Dimensions in cm of Hanford process channel.

water around the fuel. The fuel rods were arranged in a square lattice with a spacing Of 8.375 in. between the axes of nearest rods. The relevant dimensions are shown in Figure 2.

2. Infinite multiplication factor.

The infinite multiplication factor of the lattice is given by the usual four factor formula:*

$$k_\infty = \eta_T f p \varepsilon. \tag{1}$$

The value of η_T is 1.32; f can be computed from the equation

$$\frac{1}{f} = \frac{\Sigma_{aM}V_M + \Sigma_{aAl}V_{Al} + \Sigma_{aW}V_W}{\Sigma_{aF}V_F} F(\kappa_F a) + E(\kappa_M c, \kappa_M b); \tag{2}$$

p is given by

$$p = \exp\left(-\frac{N_F V_F I}{\xi_W \Sigma_{SW} V_W + \xi_M \Sigma_{sM} V_M}\right), \tag{3}$$

where

$$I = A + C\sqrt{a\varsigma}. \tag{4}$$

*The meanings of the symbols in the equations are all standard and given in the references.

The formula for ξ is complicated, but ε was computed during the design of the Brookhaven Graphite Research Reactor for a lattice of the Hanford type and is reported in BNL - 152. Its value is 1.035.

Using the following values:

$\Sigma_{aM} = 0.0003851\ cm^{-1}$	$V_M = 434.097\ cm^3$	$\mathcal{H}_M = 0.0203$
$\Sigma_{aAl} = 0.01386$	$V_{Al} = 6.028$	$\mathcal{H}_F = 0.645$
$\Sigma_{aW} = 0.0222$	$V_W = 2.905$	
$\Sigma_{aF} = 0.3668$	$V_F = 9.359$	
$a = 1.726\ cm$	$\xi_W\Sigma_{sW} = 1.46\ cm^{-1}$	$A = 2.8$
$b = 12.0$	$\xi_M\Sigma_{sM} = 0.0608$	$C = 38.3$
$c = 2.413$		$\rho = 18.6\ g/cm^3$

in Eqs. (2,3, and 4) gives f = 0.8826 and p = 0.8685. Then from Eq. (4) it follows that $k_\infty = 1.0472$.

3. Excess reactivity.

The negative reactivity introduced into a reactor due to equilibrium xenon-135 is given by the formula

$$\rho = \frac{\gamma_X + \gamma_I}{\nu p \varepsilon} \frac{\phi_T}{\phi_T + \phi_X}, \qquad (5)$$

where ϕ_T is the average thermal flux and ϕ_X is the constant 0.77×10^{13}. If it is assumed (this can be checked and

iterated upon later) that $\phi_T \approx \phi_X$, then with $\nu_X + \nu_I$ = U.0663, ν = 2.42, p = 0.8685, and ε = 1.035, it is found that ρ = 0.0152 or about 1.5 percent.

The reactivity also decreases as the temperature increases due to the negative temperature coefficient. A reasonable value of reactivity to compensate for this temperature defect is about 1 percent.

A nominal excess reactivity is therefore about 2.5 percent. For conservatism, it is probably a good idea to add about 0.5 percent, perhaps less, for miscellaneous Other negative reactivity effects - control rod sheaths, fuel and moderator impurities, instrumentation, and so on. With a total of 3 percent required excess reactivity, the corresponding value of the multiplication constant for the reactor is then

$$k = \frac{1}{1 - 0.03} = 1.0309. \qquad (6)$$

4. Reactor dimensions.

The reactor buckling is

$$B^2 = \frac{(k_\infty/k) - 1}{M^2}, \qquad (7)$$

where

$$M^2 = \tau_T + (1 - f)L_{TM}^2. \qquad (8)$$

With the values $\tau_T = 368\ cm^2$, $f = 0.8826$, and $L_{TM} = 49.3$ cm, $M^2 = 653\ cm^2$. Introducing this value of M^2 and the earlier obtained values of k_∞ and k into Eq. (7) yields $B^2 = 2.421 \times 10^{-5}\ cm^{-2}$.

For a bare cubical reactor of side ℓ,

$$B^2 = 3\left(\frac{\pi}{\ell}\right)^2. \qquad (9)$$

Inserting the above value of B^2 and solving for ℓ gives $\ell = 1106$ cm = 36.3 ft.

By surrounding the core of the reactor with a reflector, the size of the core can be reduced. The reflected length of the core becomes

$$\ell_{ref} = \ell_{bare} - 2\delta, \qquad (10)$$

where δ is the reflector savings. For the present reactor, $\delta \simeq 49.3$ cm so that $\ell_{ref} = 1007$ cm = 33 ft. This was the actual dimension of some of the smaller Hanford reactors.

5. Fuel and moderator masses.

With the reactor 33 f t on a side, there would be 33 x 12/8. 375 = 47 fuel channels per side or a total of $(47)^2 = 2209$ channels altogether. The total mass of uranium

is then 387 Te. The mass of U-235 is 0.00711 x 387 = 2.75 Te.

The moderator mass, assuming a reflector 2.5 ft thick around the entire reactor except the bottom, is then 2.25 **x IQ** ^{6} **kg**.

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APPENDIX VI-C

ELECTROMAGNETIC SEPARATION OF ISOTOPES

by

O. F. **Schuette**

ELECTROMAGNETIC SEPARATION OF ISOTOPES

Abstract

Since World War II there have been many advances in technology which are relevant to the development of electromagnetic separation of uranium on a large scale. These include magnets, pumps, controls and apparatus for carrying out the related chemical operations.

A significant contribution may be the techniques and hardware which **have** been developed for ion propulsion of spacecraft. It is necessary, however , to modify the systems to provide very intense focused beams of singly charged uranium ions instead of broad diffuse beams of elements such as cesium. Some progress has been made in the development of electrohydrodynamic sources in which ions are extracted directly from the surface of a liquid metal. A low accelerating potential may permit the use of smaller intensity magnetic fields of limited size.

If the many scientific and engineering problems can be solved, it seems possible that an electromagnetic isotope separator based on this new technology can efficiently produce enriched uranium. Because individual units are small and are able to effect a rather high degree of separation of isotopes this process may be suitable for the production of kilogram quantities of weapons grade uranium.

Introduction

The electromagnetic method for enrichment of uranium was found during World War II to be uneconomical as compared with gaseous diffusion. All of its components have been declassified and many are now available from commercial sources. Many advances have been made during the past thirty years which are relevant to this process. In this paper the possible effect of these advances on the efficiency of the system is assessed. Also, the difficulty of assembling and operating such a system by a small country with modest technical resources is estimated.

History

The electromagnetic method for separation of uranium isotopes on a large scale was developed by the United States during World War II. Nearly 500 million dollars were spent for equipment and operation. (This is nearly one-quarter the total cost of the Manhattan project and is about the same amount as was used for each of the other two major efforts, gaseous diffusion and reactors for the production of plutonium.) The Y-12 plant at Oak Ridge included 850 first-stage “Alpha” units (Calutrons) and 72 units in the second “Beta” stage. When it was shut down in December 1945 because of its low efficiency, 7000 persons were needed to keep it in operation. 1/

After the war, scientists in the United States, the United Kingdom, and the Soviet Union used electromagnetic separators developed in wartime for the protection of highly enriched samples of practically all of the elements. Electromagnetic separators for scientific research have also been developed in Switzerland, the Netherlands, Germany, Denmark, Sweden and Austria. They are now available commercially and are widely used as sources of both stable and radioactive isotopes. For these applications, milligram or gram quantities are usually sufficient.

Development Objectives

In order to make this method suitable for large-scale isotope separation it was necessary:

1. To develop focusing magnetic fields with small aberrations for large angle ion beams.
2. To design large well regulated power supplies for the source, accelerating electrodes and the magnet.
3. To develop large pumping systems to maintain a high vacuum in large volumes in which a considerable quantity of gas is released.
4. The determination of the effect of space-charge repulsion on the ion trajectories in dense ion beams.
5. The production of relatively large ion currents (about one hundred milliamperes).
6. The development of methods for the efficient collection of the enriched material.
7. The training of personnel and the development of techniques necessary for the operation of the system. The steps include:
    a. Preparation of charge material
    b. Assembly of sources and receivers
    c. Operation of the separator
    d. Extraction of the separated material
    e. Chemical refining
    f. Measurement of isotopic abundance
    g. Cleaning of source and liner

Output

Faraday's Law tells us that a 100 milliampere current of singly ionized uranium atoms corresponds to a flow from the source of 24 grams during 24 hours of operation. In case of uranium, this corresponds to 0.17 grams of U-235 per day or 0.06 kg. per year at continuous operation. In actual practice many of the ions which leave the source do not reach the collector. This is because: 1) not all of the ions which leave the source are singly charged; 2) many ions are lost from the beam in passage through the separator;

3) not all the ions which reach the collector are collected.

Overall the source-to-receiver efficiency is found to be under 10 percent for well defined foci such as are required for separation of the heaviest masses although figures of around 20 percent have been quoted for the production separators in the Oak Ridge plants. 2/

A 100 milliampere uranium isotope separator with an efficiency of 20 percent will have an output of about 5 grams of uranium a day or 0.035 grams of U-235 per day.

Space Charge Compensation

In the beam itself mutual repulsion of the positive ions would spread out their trajectories were it not for the production by collisions with gas molecules of electrons which neutralize the space-charge forces. This phenomenon has been the subject of intense investigation. It is essential for the operation of the calutron separator.

At the beginning of their trajectory, slow ions and electrons are formed in the beam. The slow moving ions drift from the beam while the electrons concentrate in the potential well at the axis of the beam. With increasing density of negative particles the potential well is gradually smoothed out while electrons and ions of sufficient energy continuously leave the beam. Finally, an “electron gas” of “thermal energies” will be concentrated in the beam. The “temperature” of this gas and the depth of the remaining potential well is defined by equilibrium between the production and loss of charged particles. 3/

Ion-Ion Scattering

1. Alexeff has found a fundamental limit to the throughput of U-235 in an electromagnetic isotope separator. 4/ Although all ions are extracted

with equal energies the lighter ones move faster than the heavier ones because of the mass difference. In addition to the azimuthal drift there is a slow radial drift in the magnetic field which is responsible for the isotope separation. Both drifts are of the same order of magnitude. When one charged particle drifts very slowly through an environment of other charged particles it is susceptible to multiple scattering. Thus, the directed relative velocity is easily lost.

Reducing the beam voltage reduces this relative velocity and increases the undesired scattering. Increasing the beam current increases the number of scattering centers and also increases the undesired scattering. It can be shown that mass spectrograph isotope separators have a limit on V^2/j, the ratio of the square of the beam voltage to the current density, due to-the scattering of U-235 ions by collisions with U-238 ions. A crude approximation by Alexeff suggests that calutron isotope separators operate within a factor of 100 of this limit.

Enrichment

The operation of an electromagnetic isotope separator is characterized by a very large isotopic separation constant (ratio of the isotopic concentration of the enriched product to that of the feed material).

It depends on the shape of the two beams, their separation and the size of the receiver slits. As beam current is increased) ion-ion scattering reduces the separation achieved, In large-scale electromagnetic separators (Alpha calutrons) the enrichment factor per cycle is usually 20 to 40. With an enrichment factor of 20 the concentration can be increased in one stage from 0.7 percent to about 13 percent U-235. (In March 1944, 200 grams of material enriched to about 12 percent U-235 had been produced by Alpha 2.) 5/

An Alpha Calutron isotopic separator which processes a total of 5 grams of uranium per day will produce about 0.3 grams enriched to 12 percent U-235 per day. (This is consistent with the estimate made in the fall of 1942 that 2000 sources and collectors were expected to be required to separate 100 grams of U-235 per day.) 6/

Tails

An advantage of the electromagnetic separator is the very low concentration of U-235 in the waste, or tails. This results in a significant saving in the quantity of uranium required as feed as compared to gas diffusion or the centrifuge which normally operate with a tails concentration of 0.2 percent U-235. Stated another way, approximately 30 percent of the U-235 contained in the feed to a gaseous diffusion plant comes out in the tails.

Apparatus

A single calutron-type separator requires a one hundred ton electromagnet with a rated power of 45 kilowatts. Two large capacity multiple stage oil diffusion pumps (rated power about 5 kilowatts each) are required to maintain the vacuum of 10^{-5} Torr. A 100 milliampere uranium tetrachloride arc ion source and a 40 kilovolt power supply are used to provide the beam which is deflected 180° in a semi-circle with a radius of 120 centimeters by the magnetic field before it enters the collector. The cost of each such separator is several hundred thousand dollars. More than a thousand of these units would be required to produce enough highly enriched uranium for one explosive per year. Even with the installation of more than one source and receiver per unit and the assembly of many units in a single magnet (Racetrack), a system based on the, calutron is simultaneously capital, labor, and energy intensive. In the form described, it would not only be the process chosen

by a country seeking to produce material for a nuclear weapon.

Prospects for Development

Advances have been made during the past 30 years in many aspects of the technology relevant to electromagnetic separators. These include ion sources, magnets, vacuum pumps, power supplies and controls. Although quantitative improvements have been made in the performance of all the components, additional development is required to make the process attractive to a country wishing to produce material for an explosive.

Ion Sources

An increase in the beam current will result in a corresponding increase in the rate of production of separated material.

1. Arc Source

After several years of intensive wartime development the uranium tetrachloride arc source was selected as superior to other candidates. It produces a large current with a relatively large percentage of singly charged uranium ions. Independent studies of sideband efficiencies from uranium tetrachloride arc sources in 180° separators at Oak Ridge and at Amsterdam show that the singly ionized uranium ions constitute 60 to 70 percent of all uranium containing ions. 7/ This compound seems better in this respect than the other uranium tetrahalides.

The beam current for these sources has up to now been limited to about 200 milliamperes because of instabilities which develop at greater values. Of course, an increase in beam current will result in an increase in the generation of chlorine which in turn requires vacuum pumps of greater capacity. High speed turbine pumps are available which may be suitable. Another problem

is the increased spread of each of the separated beams which may increase losses and decrease the degree of enrichment achieved. Some form of space charge compensation or other technique for neutralization of the beam will be necessary.

2. Electrohydrodynamic Source

During the past twenty years an intensive research and development effort has been" carried out on systems intended for ion propulsion of space-craft. One goal of this research has been the production of large currents of metal ions.

These sources are now used in microprobe for analysis. One variation uses a hypodermic needle filled with liquid metal. A meniscus at the tip is formed into a cone by an applied electric field ("Taylor Cone" with a theoretically predicted half angle of 49°). A very large local field is developed a the tip which extracts ions from the surface. The maximum ion current from a 0.005 inch diameter needle is about one hundred microampere into a large solid angle. Metals used have included cesium and gallium. Nearly all the ions produced from these sources are singly charged. ~/

R. Clampitt, Culham Laboratory, United Kingdom, has described an Electrodynamics Ion Source which uses cesium in a tube with an axial wire, at a recent conference on electric propulsion. **9/** If these sources could be developed to function as a line source (from a slit) rather than as a point large currents might be achieved, perhaps many hundreds of milliamperes.

Such sources if developed for uranium metal have several advantages as compared to the halide arc. These include:

1. Source feed would be uranium metal.

2. No filaments are needed (a continuous problem in the arc source).

3. Very small down time is required to add feed material or to remove product.

4. pumping requirement would be relatively small because no gas is evolved from source.

5. If uranium behaves in a manner similar to cesium or gallium all of the ions will be singly charged (no side band losses).

6. Since a lower pressure could be maintained in the separator, there may be less loss of ions from the beam. A higher source-to-collector efficiency might result.

There are also problems to be solved:

1. Achievement of a large uranium ion beam current in a high vacuum chamber will result in a spread of the beam due to mutual repulsion of the ions. Some technique for neutralization must be developed. Also the maximum current will be limited by ion-ion scattering.

2. Suitable materials for fabrication of the source must be found. It will be necessary to have molten uranium (1300°C) maintained at **a** constant temperature.

3. Techniques for maintaining stability of the beam must be developed.

4. Extracting and accelerating electrode structures must be designed. In order to have a smaller magnet it would be desirable to have lower accelerating voltages. (The 40 kilowatt accelerating potential used in the Calutron is necessary in part to optimize space charge compensation.)

Magnet

The hundred-ton forty-kilowatt magnets were required for the 180°, 120 centimeter radius Calutron in order to give an adequate spacing between the U-235 beams and U-238 beams. This resulted in a system with a separation factor of 20 to 40.

A modern approach to this problem might use a half-toroid tank with the field provided by small permanent magnets or electromagnets.

If a system were designed for lower velocity ions (accelerated by 10 kilovolts instead of 40 kilovolts) a much less intense magnetic field would

suffice. For a constant radius of deflection, reducing the voltage by a factor of four will result in a reduction in the required field by a factor of two.

Another approach which has been successfully used in mass separators for scientific applications is to use a 90° deflection. A 90° sector machine is arranged with the source, the center of curvature of the ion path, and the collector on a straight line. In this geometry both the source and the collector are one beam radius from the edge of the magnetic field. This arrangement permits the use of a smaller magnet.

Manpower Requirements

The procedures required for operation of a systems such as this which involves a “batch” process is intrinsically labor intensive. An essential part of the development will be the training of technicians to service the sources and receivers, to operate the separator and to carry out the necessary chemical procedures on the output. In order to provide one person per unit in three shift operation, about three trained personnel will be required for each unit. Approximately one half the work force will supervise the actual operation of the separators, the rest will provide the other essential services.

Possibility of Proliferation

Two scenarios will be considered, the first to assemble an electromagnetic isotope separation plant large enough to **produce material** for a single explosive each year (15 kilograms of fully enriched material) with a minimum of development and a maximum use of off-the-shelf items. The second is to develop the necessary components and to build a plant of the source capacity which might

produce enriched uranium at a cost comparable to that of the centrifuge or gaseous diffusion processes.

1. "State-of-the-art" Plant

In order to initiate the program several 90° sector electromagnetic separators would be obtained through commercial channels. Possible suppliers include companies in the United States, United Kingdom, Switzerland, the Netherlands, Denmark, Sweden and Germany. These units which cost about two hundred and fifty thousand dollars apiece should have a sector radius of about 60 centimeters, more than 10 centimeter gap, and a magnetic field of more than 8000 Oersted. Ion sources, pump collectors and power supplies would be purchased with each unit. Several high capacity turbine vacuum pumps should be ordered at the same time.

Prototype uranium tetrachloride arc courses and receivers must be fabricated. Published designs are available and would be the basis for this essential development. The first models would be designed to be used with the commercial isotope separators. These tasks must be carried out in a well equipped machine shop.

At the same time that the research isotope separators are ordered, design and construction of a prototype production unit must be started. Nearly all of the features have been described in the scientific literature. Some of the components can be obtained commercially. Others can be copied from the purchased units. For example, it is possible that suitable electromagnets could be fabricated in a plant which manufactures large transformers. The ion source, receiver and the tank might be produced by a factory which produces major electrical appliances.

At least two years will be required to fabricate the sources and receivers and develop techniques for their operation with the purchased separators. It is likely-that the prototype of the production unit designed during this period will also be a 90° sector machine. Another year of development will be required before the performance of this unit can be evaluated. It seems probable that this unit would have a few hundred milliampere beam and an efficiency of about 20 percent.

A cost estimate for the Calutron Process was a part of a review of methods for uranium isotope separation which was made by an ad hoc committee in 1972. 10/ Using up-to-date costs and incorporating known improvements they predicted costs per gram of U-235 ranging from $160 (for a beam of 600 milliamperes reached with minimum development) to $9 for a unit with beam current of the maximum value permitted by ion-ion scattering (40 amperes). The lower cost is more than that for enrichment to weapons grade material by gaseous diffusion. It is likely at the largest beam currents that the enrichment would, in fact, be very low. Also the development costs to achieve the high currents were estimated to be very high.

A minimum total cost of 100 million dollars is estimated for the construction of a plant based on calutron separator technology. It could not be attempted by a country which does not have considerable scientific and industrial resources. The size of the country and the large number of persons involved would make it very difficult to conceal.

2. Advanced Design

In order to make this isotope separation process more attractive than gaseous diffusion or centrifuge it is necessary to develop relatively cheap,

small units which can handle large ion currents. It also will be essential to reduce the cost and complexity of the auxillary operations.

In order to get away from the corrosion, chemical processing and pumping associated with chlorine it may be desirable to develop a substitute for the uranium tetrachloride arc source. A possibility is an electrohydrodynamic ion source which would operate with liquid uranium metal. A singly ionized uranium beam of more than one ampere is needed. It is also important to develop a system with low accelerating voltage so the required magnetic field will be significantly reduced. This may make feasible the use of permanent magnets in a small 90° sector machine. Improved vacuum and geometry of the receiver may result in a rather high source to receiver efficiency. The commercial development of a unit of this type has been proposed by PHRASOR. Although they have apparently done little laboratory work, they estimate a four-year development at a cost of 30 million dollars of a plant to produce annually 30,000 kg of uranium enriched to 3%. n_/

In order to attempt this development a staff of at least twenty research physicists and chemists and an equal number of electrical, mechanical and chemical engineers with design experience will be needed. It will be essential to recruit at least one person who has been working on the relevant technology in ion propulsion.

If the goals described above are met, a unit would result which has a one-half ampere beam, efficiency of as much as eighty percent and a separation factor of about 4. It would produce approximately 15 grams per day of a product containing 3 percent U-235. The cost of such a unit might be as low as $50,000, not counting the research and development costs.

A plant based on units with this performance would require 33,000 separator days to produce 15 kilograms a year of U-235 in 3 percent material. (This is 500 kilograms of enriched uranium.) Assuming 333 days of operation per year about 100 Alpha separators will be needed. An additional 50 units would be required for additional stages needed to produce weapons grade material.

The development program will require at least five years and might cost in the neighborhood of several tens of millions of dollars. A minimum cost for a two hundred unit plant might be about fifteen million dollars. It could be built in about two years after development of the prototype enrichment unit.

This development could only be accomplished by industrialized countries with an established scientific and engineering infrastructure.

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11. PHRASOR TECHNOLOGY INCORPORATED, 110 South Euclid Avenue, Pasadena, California, 91101.

APPENDIX VI-D

URANIUM LASER ISOTOPE SEPARATION

AND

NUCLEAR WEAPONS PROLIFERATION

(UNCLASSIFIED VERSION)

Prepared for the Office
of Technology Assessment

by the

United States Energy Research
and Development Administration

URANIUM LASER ISOTOPE SEPARATION AND NUCLEAR WEAPONS PROLIFERATION

This paper has been prepared in response to a request from the Office of Technology Assessment (OTA) for ERDA assistance in evaluating the proliferation implications of laser isotope separation (LIS). OTA will use this paper in the preparation of its assessment of Nuclear Proliferation and Safeguards which it is performing for the Senate Committee on Government Operations.

The OTA has requested that ERDA address the following specific topics:

1. A description of the technology.
2. Informed judgments on the proliferation implications of the technology five to 20 years hence
   a) with respect to the LDCs (Less Developed Countries)
   b) with respect to non-state organizations (i.e., terrorist or criminal).

   The case to be considered would be a laser isotope separation plant producing the order of magnitude of 100 kg of > 50% U-235 per year.

   c) an assessment of the feasibility of modifying an LIS process, which has been designed for low enrichment only, to yield high enrichments.
3. The possible indicators (personnel, equipment, etc.) in international or domestic trade that would provide an “early warning” of the construction of a clandestine LIS plant.

4. The possibility of detecting a clandestine LIS plant by physical surveillance (e.g., from satellite, aircraft, or other means).
5. An estimate of the efficacy of classification and export controls in delaying spread of the technology (i.e., how much time classification and export controls can buy).
6. An assessment of the problems and prospects of safeguarding an LIS facility.

1. Description of the Technology*

A. Introduction

The existence of differing atomic and molecular isotopic energy levels permits selective excitation of a given isotope by narrow band lasers. A generalized two-step process for Laser Isotope Separation (LIS) is illustrated in Figure 1. In the first step, the photons of a particular energy, $h\nu_1$ are absorbed by isotope "A" of an atomic or molecular mixture but not by isotope "B". The excited "A" atoms, or molecules, are then ionized or dissociated by photons of energy $h\nu_2$. The product of the reaction would then be separated to yield the enriched isotope.

The lasers required for isotope separation must have wavelengths which are narrow enough to take advantage of the isotope effect and must also have a sufficient power and repetition rate to react with a reasonable quantity of the desired isotope. These requirements are currently well beyond the present state-of-the-art.

Two LIS processes are currently under intensive development by ERDA; one is based on the excitation and dissociation of uranium hexafloride and the second based on the excitation and ionization of atomic uranium vapor.

B. Molecular Process

The molecular process being developed at the Los Alamos Scientific Laboratory. This method uses the isotonically selective

* A few classified sentences and phrases have been deleted from Section I.

laser irradiation and dissociation of gaseous UF_6 molecules. The action of the lasers causes one isotopic form (either ^{235}U or $238U$) to break up, yielding UF_5 which rapidly condenses. Thus, the selective chemical action of the lasers is to preferentially convert a gas to a solid of the desired isotope. The solid UF_5 particles which are produced are then removed from the UF_6 process stream.

The molecular LIS process will not work at ordinary gas temperatures under ordinary gas flow conditions, but unique operating conditions have been devised for successful exploitation of this process. At ordinary temperatures the spectrum of UF_6 does not exhibit distinct isotopic characteristic features. Due to complex vibrational motions of the molecules, a single light frequency would excite both ^{235}U and ^{238}U. However, it has been demonstrated that if the UF_6 gas is cooled to very low temperatures (approximately 50 degrees K), these interferences are removed and distinct isotopic characteristics are obtained. To achieve the low temperature, UF_6 gas is mixed with a carrier gas and expanded through a nozzle to supersonic velocities. The nozzles are built with long slits for the expansion throat in order to facilitate passage of laser beams through the fast moving flow. Upon exiting the nozzle throat, either $^{235}U_6$ or $^{238}U_6$ can be selectively irradiated using appropriately chosen infrared lasers.

Once a particular isotope has been vibrationally excited by a tuned infrared laser, light from a selected ultraviolet laser then

adds **sufficient energy to** cause dissociation into UF_5+ F. The UF_5 **species mutually** condense to form solid particles to be collected as the enriched product. At the present time the research effort is devoted to analyzing various process options, investigating possible **scrambling** effects which may interfere with efficient collection of the isotopic products, and developing the lasers required for the separation.

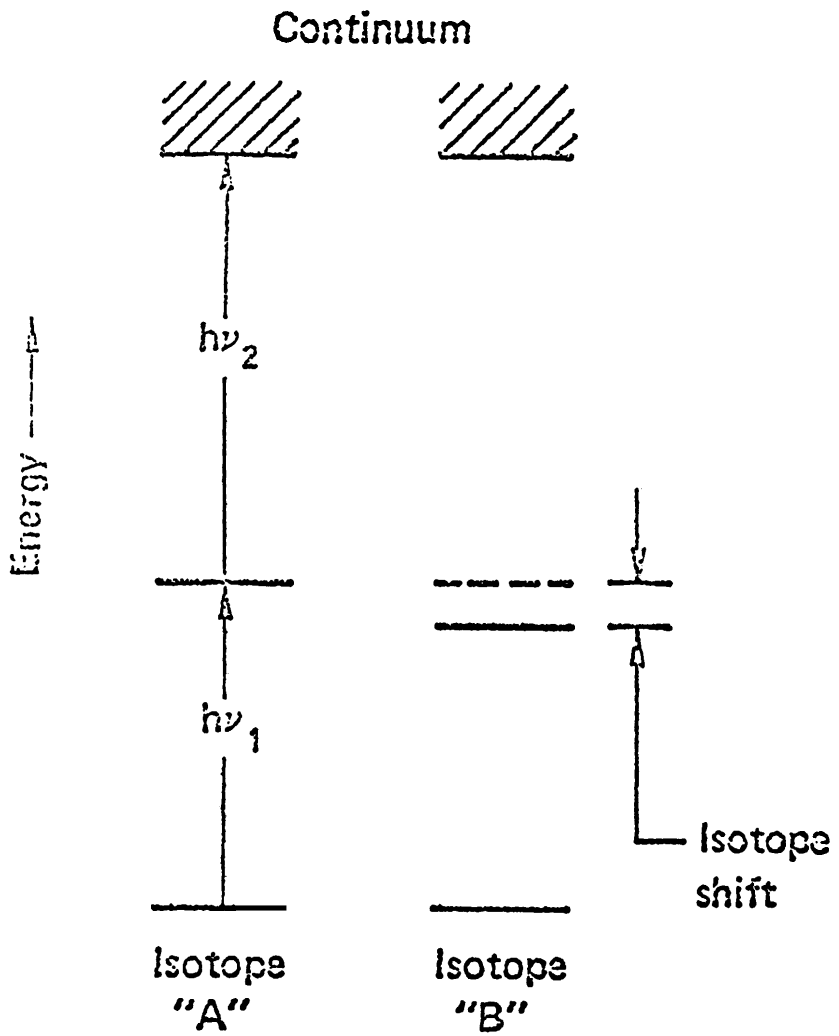
C. Atomic Vapor Process

Lawrence Liver-more Laboratory is developing an LIS process based on the isotopically selective photoexcitation of atomic uranium vapor. The atomic vapor process uses uranium metal as a feed material rather than UF_6. The atomic vapor process consists of three main sub-systems: (a) a source of uranium vapor, (b) a laser system capable of selectively exciting/ionizing the particular isotope desired, and (c) a technique for extracting the excited isotope from the isotonically mixed vapor and a collection system for handling the depleted tails and **enriched** product. Uranium vapor producing concepts considered to date are high temperature (equilibrium) sources of pure uranium and non-equilibrated sources of pure uranium vapor (electron beam bombardment).

Many lasers for the enrichment of atomic uranium vapor have been proposed. Because of the complex electronic structure of the uranium atom, and the distribution of the electrons among various energy levels at the working temperature, selective excitation and ionization

can be **attained by a variety of** routes. The simplest one involves the use of two ultraviolet photons for the excitation and ionization steps. If an N-photon ("N" designating three **or more** photons) system is used, more lasers of differing frequencies may be required; however, such systems may be operated at wavelengths where dye lasers are more efficient. In variations of the N-photon scheme, the more efficient CO_2 infrared laser may be used to provide the final energy to ionize the excited uranium 235 atom.

FIGURE 1 GENERALIZED TWO-STEP PR CESS FOR ISOTOPE SEPARATION USING LASERS



1. Photons of energy $h\nu_1$ are absorbed by "A" but not by "B"
2. Excited "A" atoms (or molecules) are ionized (or dissociated) by photons of energy $h\nu_2$
3. Ions (or molecular fragments) are collected by physical or chemical processes

II. Proliferation Implications

This section examines the potential impact of LIS technology on the possible spread of nuclear weapons to additional countries. The various LIS efforts are only in an early state of development and will take some time to bring to production scale. Because it is difficult to judge the magnitude of threat from the standpoint of proliferation, statements concerning the possible impact of LIS are largely hypothetical. The effect of LIS technology on nuclear proliferation will depend to no small degree on the specific nature, cost, and the timing of the technology that ultimately emerges as the most feasible. In this connection, it should be noted that even though commercial feasibility is estimated to be at least 10 years away with additional time required to build a full-scale plant, use of LIS for small weapons programs could occur sooner.

11½ pages of classified material have been deleted here.

Although the development of LIS would increase the risk of proliferation, it would not in and of itself necessarily lead to the spread of nuclear weapons. The availability and cost of LIS technology are not the only considerations which may lead a country to acquire nuclear explosives or to select LIS as the preferred route to a nuclear explosives capability. A decision by a nonnuclear-weapon state to acquire a nuclear-weapons or other nuclear-explosives capability would depend on a number of complex political, diplomatic and military considerations. Many countries which already have the capability to develop nuclear weapons have decided for foreign policy or other reasons to foreswear the acquisition of nuclear weapons. In the final analysis, a country's perception of its national security needs will probably be the most important factor in any decision to develop nuclear weapons. However, even in a case where the national security situation may warrant the acquisition of nuclear weapons, a combination of political constraints may tip the balance against acquiring them.

A lack of resources could also prevent a country which might otherwise wish to embark on a nuclear weapons program for doing so or, at least, greatly inhibit its efforts. Special nuclear material could be a key factor insofar as it would ordinarily be the limiting resource in the case of most non-nuclear countries which seek to acquire nuclear weapons. If such countries could not obtain nuclear weapons or special nuclear material directly from an external source, i.e., through theft or purchase, their basic options would be either to use fissionable material produced

through their peaceful nuclear power or research programs or to initiate a new program to produce special nuclear material.

Most special nuclear material used in peaceful nuclear programs is presently subject to safeguards applied by the International Atomic Energy Agency and is also subject to some sort of peaceful uses guarantee by the consumer country. Non-nuclear weapon states party to the Treaty on the Non-Proliferation of Nuclear Weapons have undertaken to accept international safeguards on all their peaceful nuclear activities and have agreed not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices.

Any country considering diverting material for use in a nuclear weapons or nuclear explosives program would have to consider the significant political, legal and other costs associated with such an act. In the case of U.S.-supplied materials or equipment, such an act would be an abrogation of a legal agreement with the United States not to use U.S.-provided material or equipment for military purposes which we have construed as including development or use of any nuclear explosive device. Similar considerations would apply to the diversion of materials or equipment supplied by other nuclear exporting countries. Parties to the NPT would, moreover, be abrogating a commitment to all their treaty partners. The potential diverting country would have to assess the reactions of the United States and the international community, . particularly its immediate neighbors, who might feel threatened by such an action. Such an assessment would have to be made in a decision to divert material from any facility, whether LIS, gas centrifuge or a plutonium production or utilization facility that is subject to international safeguards and peaceful use guarantees.

No such abrogations have occurred to date. However, it is impossible to determine whether these considerations would outweigh a given country's perceived need to acquire a nuclear explosives capability.

A country could-also decide to develop a nuclear explosive using unsafeguarded, undeclared or military facilities. One option would be the use of such facilities to produce plutonium. Although few non-nuclear countries have unsafeguarded plutonium available, many already have or could develop the capability to produce plutonium indigenously. Unclassified technology for constructing the needed facilities is readily available and generally well understood. Countries with advanced nuclear programs would be in an especially good position to carry out such a program. Given a supply of plutonium, many of these countries could then manufacture nuclear weapons of a crude implosion design. In fact, less plutonium would be required per weapon than in the case of enriched uranium.

The time required to build unsafeguarded reactors, fabrication plants, and reprocessing plants to generate plutonium, and eventually to manufacture a few rudimentary weapons, would take perhaps four to six or more years for the more advanced countries to 10 years or more for less-developed countries. If the means of delivery of such rudimentary weapons were of secondary importance, even a rather unsophisticated means of delivery might prove adequate. More advanced non-nuclear countries might, of course, wish to develop a modern nuclear strike force including a moderately sized stockpile, which would undoubtedly take more time than the four to six years required for rudimentary weapons.

If on the other hand, LIS technology were generally available, countries going nuclear may be more apt to select the uranium route

since, other things being equal, it would present fewer problems than the plutonium route. In contrast to uranium, the radiotoxicity of plutonium would create a handling problem. In addition, the costs and technological requirements of constructing and operating a moderately advanced, small-scale (but militarily useful) centrifuge plant could be less than a large reactor-plutonium facility. These points would probably apply to LIS plants as well.

Moreover, natural uranium, the basic source for feed for LIS plants, is widely available, and a number of countries have significant, reasonably assured deposits of uranium ore. Even countries without deposits of uranium ore, however, could probably find a source willing to sell them the material. The other parts of the uranium cycle would present no insurmountable problems for many non-nuclear weapon countries.

In the final analysis, the question of whether a given country would decide to utilize LIS technology rather than some other means to acquire a nuclear explosives capability depends on a number of imponderable factors; the availability and economic cost of **LIS** technology vis-a-vis other technologies; the nature and urgency of its political and military objectives; its ability to acquire the necessary equipment and technology without any “strings attached”, and its willingness to abrogate solemn international commitments.

The Threat from Non-state, i.e., Subnational Organizations

The widespread development of LIS technology might also result in the increased availability of special nuclear material to terrorist or other subnational groups. This danger has two sources: (1) the possibility of using the technology directly to obtain special nuclear material, and (2) the likelihood of significant stockpiles of this material in many locations thus increasing opportunities for theft.

However, capabilities of non-state organizations in the near term are believed to be extremely low.

111. Foreign LIS Program Intelligence Indicators

a. Difficulty of Identification

It is difficult to positively identify a definite ongoing program or research in areas leading to such a program in most foreign countries. The several separation techniques and processes are in their infancy and in many cases, as stated, information for analysis of these processes is severely limited. Certainly, no large easily-identified complex such as with gaseous diffusion separation is necessary for a research program in LIS. Also research in areas which may touch upon one or two of the critical indicators of a laser isotope separation (LIS) program does not necessarily mean the existence of one. The research may apply to some other technology. Therefore, a matrix of critical intelligence indicators taken together is the only reasonable means of identification.

b. Intelligence Indicators

An attempt has ken made to establish what are the individual technology-related intelligence indicators. The following list of critical areas and indicators leans toward the LASL approach. As more research and information become available, additional items should be included. Not included is the obvious need to identify scientists and assess their potential.

In general, one would be interested in analyzing research, interest, or stated goals in photochemistry, high resolution spectroscopy, and high power tunable lasers. Other information would include **that**

related to (1) semiconductor diode, gas, and/or dye lasers; (2) wavelengths (or frequencies), power levels, pulse repetition rates, or constituents of lasers; (3) concern with high purity feed material, or fluorine corrosion of equipment, especially compressors; and (4) research and lasing-related equipment compatible with specific infrared and ultraviolet wavelengths of ^{235}U ^{238}U UF_6, and carrier gases.

Intelligence Indicators for Laser Isotope Separation (LIS) Research

The ** indicates the most important indicators, a single * indicates next in importance, etc.

A. High Resolution, Laser Spectroscopy

1. Study of absorption spectrum of uranium, as well as other possible elements in combination with uranium.

** 2. Study of the exact frequencies of uranium isotope absorption lines. (7.7, 8.6, **12.1,** 16μm in the ir and around 0.4μm in the UV)

3. Low power tunable lasers to operate over a narrow range around those wavelengths. (μ joule/pulse sufficient)

a. Semiconductor diode lasers for spectroscopy tunable to the ir frequencies in question. (Atomic ratios specified)

b. Dye laser for uv spectroscopy (LASL uses N_2 pumped dye laser of p-quaterphenyl)

c. No particular requirement for pulsing.

B. High Power Irradiation Laser Systems

1. Infrared-range lasers

** a. Capable of high energy outputs

** b. High pulse rates

** c. Tunable over narrow ir range in question.

d. Gas Lasers

* (1) Physically large (e. g., TEA lasers for few mJ/pulse is 4 x 4 cm by 150 cm long)

(2) Use of TEA (Transverse Electric Atmospheric-pressure) laser for high energy output at high pulse rate.

(3) Use of gases which can lase at or near 7.7-16μm wavelengths. (e.g., CO, CO_2, OCS, CF_4, CS_2, C_2H_2, $CHBR_3$, C_2HD)

(4) Use of non-linear optical techniques to "downshift" frequencies of laser beams to regions of program interest.

2. Ultraviolet Range Lasers

** a. Capable of high energy outputs.

** b. High pulse rates

** c. Tunable over narrow range in the 0.2 to 0.4 μm wavelength region

d. Organic Dye Lasers

* (1) Physically large

* (2) Use of dyes with spectrum which brackets that of interest.

** (3) Solvents in which dyes dispersed must be optical (UV) grade and used in quantity.

(4) May have optical device for fine tuning.

(5) Work on high repetition rate dye laser systems.

C. Components -for Tuning Lasers

1. Superconducting air core magnets (perhaps 50-100 KGauss)

2. Crystals

3. Use of Raman Spin Flip (RSF) process to downshift emerging beams from crystals.

4. Optical gratings other frequency selective devices.

** 5. High reflectivity mirrors used to manage laser beams, made for wavelength of light to be reflected.

** 6. AM-reflective coatings, wavelength specific

D. Feed Material and Processing (The Atomic beam process would not be concerned with fluorine problems.)

* 1. Use of rapid cooling of UF_6 through spersonic expansion nozzle in order to collapse absorption spectrum.

* 2. Process for separating solid from gas. **(UF_6, $^{235}U F_6$)**

3. Concern with fluorine corrosion.

a. Extensive use of nickel or Monel to avoid fluorine attack.

c. Teflon-coated elastomeric O-rings. (Solid teflon tends to creep and other elastomers are chemically unstable)

** c. Contamination-free fluorine-compatible gas compressors.

E. Diagnostic Equipment

1. HF chemical lasers - tool for analyzing for traces of HF impurities in gas samples.

2. Modification of mass spectrometer for analysis of fluorine-related gaseous compounds.

3. Plasma diagnostics with lasers (e. g., cw He Ne, low power CO_2, high power pulsed CO_2 and ruby) done in single pulse mode, probably no fine tuning.

F. Electrical Equipment and Requirements

* 1. Energy storage and pulsing apparatus.

(1) Capacitors to store 10-100 times electrical energy as laser will deliver per pulse.

2. Switching Equipment. (large scale)

** 3. Electric Power into laboratory appropriate to serve a laser.

** 4. Electrical noise on telephone or power lines serving a laser lab, indicating pulse rates.

IV. DETECTION OF CLANDESTINE LIS PLANTS BY SURVEILLANCE

LIS technology would likely have small space and electrical power requirements. Hence, significant amounts of enriched uranium production could be carried out with little chance of detection. With the possible exception of some covert means, current detection systems would be of limited use. Thus the process would lend itself readily to the establishment of a clandestine facility.

Tracking feed material would not necessarily facilitate detection of a clandestine LIS facility. First, uranium ore production can be a by-product operation associated with other mineral mining activities, e.g., gold mining in South Africa, phosphate mining in Brazil, Israel and the US, and copper production in the US. In such a situation, not only would uranium mining become less costly, but the uranium mining operations could be more easily concealed. Second, uranium milling

operations usually take place near the site of the mine so that, even though it may take 2000 metric tons of uranium ore to provide enough U-235 for a critical mass quantity (about 50 kgs bare sphere or about 20 kgs if reflected), the equivalent uranium ore concentrate actually shipped from the mill to the conversion plant would only be about 4 metric tons. The associated feed, metals processing and even the weapons fabrication facilities could be relatively small operations, which could easily be performed within the enrichment facility itself. To illustrate, a supply of ten metric tons of purified UF_6 or elemental U per month to a clandestine LIS plant could be delivered by one large truck, and could enable the plant to produce about 30 critical masses per year if complete separation of U-235 were achieved.

V. Efficacy of Classification and Export Controls in Delaying Spread of LIS Technology

A. Current U.S. Classification Policy

Section lly. of the Atomic Energy Act of 1954, as amended, define Restricted Data to include:

> "all data concerning (1) design, manufacture, or utilization of atomic weapons; (2) the production of special nuclear material; or (3) the use of special nuclear material in the production of energy"

except data which have been removed from the Restricted Data category or declassified upon determination pursuant to Section 142, that such data could be published without undue risk to the common defense and security.

In the area of isotope separation as with other atomic energy information, classification of information in the Restricted Data category is designed to prevent unauthorized disclosure of technology and equipment which would be detrimental to the common defense and security of the U.S.

Current ERDA policy provides that "research and development work on any method of isotope separation . . . would be unclassified as long as the Administrator is satisfied that the method does not have a reasonable potential for the separation of practical quantities of special nuclear materials." Methods judged as having such potential are classified as Restricted Data.

In the area of LIS, both processes described in this report (LASL and LLL) have been determined to fall into the category requiring classification under this policy. However, since the principles of LIS are not novel and many of the concepts involved in the development of LIS technology have been described in the open literature, it is not reasonable to attempt to classify everything about the U.S. LIS processes. Rather, our classification policy requires protection of process details such as unique design and engineering features and operating parameters, which appear critical to achieving a successful process.

Classification of Isotope Separation .Technology in the Private Sector

The definition of Restricted Data set forth in the Atomic Energy Act of 1954, as amended, encompasses information generated in the private sector as well as information developed by or on behalf of the U.S. Government.

Any privately generated information classified as Restricted Data under the Act must be protected in accordance with the various requirements of the Act and ERDA's implementing regulations, including the requirements for physical security of facilities, the requirement for security clearances for all individuals having access to the information and the prohibition against communication of that data to any other nation.

In order to help assure that the U.S. Government is aware of all private work in areas which could come within the Restricted Data (RD) definition and therefore require classification, section 151c of the

Atomic Energy Act requires that any discovery useful in the production or utilization of SNM must be reported to ERDA or to the Commissioner of Patents:

> "c. Any person who has made or hereafter makes any invention or discovery useful in the production or utilization of special nuclear material or atomic energy, shall file with the Commission a report containing a complete description thereof unless such invention or discovery is described in an application for a patent filed with the Commissioner of Patents by such person within the time required for the filing of such report. The report covering any such invention or discovery shall be filed on or before the one hundred and eightieth day after such person first discovers or first has reason to believe that such invention or discovery is useful in such production or utilization.

In addition, regarding isotope separation work, ERDA has issued notices in the Federal Register providing information on what areas of development may come within the definition of RD and when ERDA should be informed of the status of such work, so that classified work is performed only under proper security controls and restrictions. The following is the text of the latest such Federal Register Notice dated August 1, 1972 regarding advanced methods of isotope separation, which includes work in the area of LIS.

Excerpt from Federal Register, Volume 37, No. 148 -- Tuesday, August 1, 1972, Page 15393

NOTICES

NOVEL METHODS OF ISOTOPE SEPARATION

Procedures for Reports on Research

The AEC has reviewed its declassification actions in the field of isotope separation to assure that they are consistent with the policy expressed in section 141 of the Atomic Energy Act, and to determine whether any further actions to ensure the common defense and security are to permit and encourage the free

interchange of ideas and criticisms are now appropriate in the light of the current state of the relevant technology. In this review the Commission has focused on the classification status of methods of isotope separation other than gaseous diffusion and gas centrifugation. In 1967, the Commission declassified all research and development work concerning any such other method of isotope separation until that method has a reasonable potential for the separation of practical quantities of special nuclear material. The public was notified of this action by a statement published in 32 F.R. 20868.

The Commission has reaffirmed that determination as best meeting current needs. It has also noted that as unclassified research and development on any such other method of isotope separation proceeds, there may come a stage at which the researcher will need classification advice in order to assure that classified work is performed only under proper security controls, and that correct and timely classification determinations are made, so that any restricted data involved would be protected in accordance with the Atomic Energy Act. Therefore, any person engaging in research and development on such other methods of isotope separation should notify the Commission when, in his opinion, the process has demonstrated, through experiments in the laboratory or through theoretical studies or calculations, that the process can separate uranium isotopes, so the Commission can give him appropriate classification and reporting guidance. Prompt guidance will be given. Reports should be submitted to Director, Division of Classification, U.S. Atomic Energy Commission, Washington, D.C. 20545.

Any researcher who believes his work may have proceeded to the point where it is no longer unclassified should proceed in accordance with 10 CFR Part 95, especially § 95.32.

Dated at Germantown, Md., this 28th day of July 1972.

W. B. McCool,
Secretary of the Commission.

[FR Doc.72-11917 Filed 7-31-72;8:48 am]

B. Efficacy of Classification

Classification of unique features or details of any new process, such as LIS, can make it more difficult for non-nuclear weapon states or non-state organizations to acquire enrichment process information which potentially may offer a relatively inexpensive means of acquiring SNM.

Our experience with older isotope separation processes should be noted here. Certain U.S. gaseous diffusion technology has remained classified for over 30 years and, while this has not prevented some other advanced industrial nations" from independently developing

similar capabilities, classification has been a factor in preventing wide proliferation of this technology to many countries. Gas centrifuge is an example which applies even more directly to the LIS question. In this area, classification has been applied to significant features of U.S. work since 1960 and experience has indicated that this policy has been very effective in protecting unique U.S. developments. Again, classification by the U.S. cannot prevent other countries from developing indigenous capabilities through independent invention of the technologies. In the area of gas centrifuge, however, the U.S. was successful in arriving at an informal quadripartite agreement in 1960 with those Governments doing major development work, i.e., the UK, the FRG and the Netherlands, regarding classification of gas centrifuge technology. While other countries such as Italy, France and Japan continue to pursue some gas centrifuge work without an agreement to classify it, these countries do not have major programs and furthermore have not published their work.

Similarly, in the LIS area, classification of technology by the highly industrialized nations should serve to retard the progress of other countries in developing this method. However, it will be important to involve as many nations as possible in a common classification policy, starting with potential suppliers, and extending if possible to all nations with active LIS programs.

As a goal, an agreement should be reached with all nations working on any isotope separation methods to protect significant technology. Initial steps toward this goal are currently being pursued by ERDA in conjunction with the State Department.

It must be understood that national or even international classification provides only transitory protection for technology. It cannot guarantee that similar LIS processes may not be developed independently by other nations. Since LIS is a highly sophisticated technology, however, if classification is applied uniformly by all industrialized nations involved in development work, it could prove to be effective in delaying the spread of the technology. If other industrialized nations are not willing to classify their LIS developments, classification by the U.S. of our own work will still have some retarding effect on proliferation of the technology, but since many other countries are already working on LIS processes, the overall effectiveness of U.S. classification will depend on the significance of U.S. advances versus developments in other countries.

Export Controls

Special nuclear materials as well as Restricted Data can only be exported under a government-to-government agreement made pursuant to Section 123 of the Atomic Energy Act. Therefore, the U.S. has the mechanism for adequately reviewing proposed exports of classified items.

The U.S. Government also has extensive export controls over unclassified equipment, technology and materials in the uranium isotope separation area.

The principal restriction on the export of U.S. unclassified information and equipment is set forth in Section 57.b. of the Act*, which states it shall be unlawful for any U.S. citizen to directly or indirectly engage in the production of any special nuclear material outside of the United States except (1) under the Agreement for Cooperation, or (2) upon authorization by the ERDA after a determination that such activity will not be inimical to the U.S. interest.

The implementing ERDA regulation, 10 CFR 810, requires a specific authorization from the Administrator of ERDA for any U.S. person or company to engage in activities outside of the U.S. pertaining to designing, constructing, fabricating, furnishing, or operating facilities for the separation of isotopes of uranium or equipment *or* components specially designed for such facilities. The same requirement includes

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*There are some items of equipment and materials useful in nuclear facilities that are controlled by the Department of Commerce. Some of these items can be exported under general authorizations; however, those items requiring a specific Commerce *license* are referred to the ERDA for recommendations=

the training of foreign personnel or furnishing of information not available to the public in published form.

Present export controls are comprehensive and should be adequate to control newly developing technologies or specially designed equipment. However, these export controls are effective only if significant items are identified and regulated through U.S. export control regulations. Since the LIS process is still at the R&D laboratory stage of development, it is not yet possible to identify all the significant items and know-how that should be controlled for national security reasons. As these items are identified, export licensing controls can be extended to cover them.

At present, the U.S. Government exercises export controls lasers and laser systems and specially designed components and parts of such systems, including amplification stages, and any equipment containing, or which is designed to contain, lasers. Controls are not applied, however, to low-power lasers and to certain specified civil equipment containing lasers, such as those commonly used in medical applications, educational devices, and clearly civil commercial applications.

Export controls cannot prevent another nation from independently developing a uranium isotope separation capability. At best, they could retard development and increase costs of the foreign process, if the U.S. has unilateral control over certain important technologies, equipment and material used in the process.

VI. Safeguards

The impact of LIS on the current system of international safeguards is potentially complex and far reaching. It should be recognized that the application of safeguards to existing enrichment plants is already a complicated problem.

The international safeguards[1/] which have been developed to ‘ate by the IAEA appear to be reasonably complete and adequate for all phases of the nuclear fuel cycle from the chemical conversion stage onward except with respect to isotope separation plants. The reason international safeguards on such plants have not yet been fully developed stems from two factors. First, international safeguards tend to conflict with the requirement to protect the classified and proprietary information of such plants from dissemination to international inspectors. The IAEA, under U.S. and European pressure, seems to be arriving at a system of perimeter safeguards to achieve such protection, although many details relating to this system have yet to be worked out. Second, the need for such safeguards is only now arising, i.e., at the Almelo centrifuge facility in The Netherlands.

Apart from the possible calling into question of the basic validity of the current international safeguards system, the major implication for safeguards of LIS technologies is that, by making it much easier and

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1/ Comprised mainly of nuclear material accountability augmented by containment surveillance techniques. Physical security is applied by individual governments with guidance in the form of IAEA-sponsored recommendations.

cheaper to enrich uranium, they would increase the importance of material containing low concentrations of U-235 (i.e., source material and depleted uranium), by substantially reducing the cost of enrichment.

The potential of LIS to achieve high separation in a few steps is particularly noteworthy in this regard. Thus, these technologies would have the effect of increasing the significance of uranium mining, milling, refining, and conversion facilities, from the safeguards standpoint. Extension of **IAEA** inspections to cover these processes as well as **loca-**tions containing quantities of depleted uranium from present enrichment plants, would tend to alleviate the problem, but the political and administrative feasibility of such extensions is questionable. In any case, as noted earlier, there are other sources of natural uranium which cannot be controlled.

Apart from the question of the increased significance of material containing low concentrations of U-235, there is the problem of devising national and international safeguards for prevention or deterrence of diversions of highly-enriched material from declared national LIS facilities. On the one hand, if the LIS techniques were widely utilized, the enrichment plants would be much more numerous; perhaps of such a nature that each constantly produced weapons-usable material which might be diverted during any brief lapse in inspection coverage. On the other hand, the necessary surveillance could be performed by IAEA inspectors or possibly by unattended instrumentation. Surveillance by IAEA inspectors might tax IAEA capabilities if many countries built such plants.

In addition to safeguards problems related directly to LIS plants, another problem stems from the possibility that such plants might lead to a large increase in the presence of highly-enriched uranium in other parts of the fuel cycle. This situation would increase possibilities for diversion and hence increase the required intensity of domestic physical security measures and international safeguards.

The most complicating feature of the LIS technologies with respect to safeguards is their potential for clandestine production of weapons-grade material. International safeguards as they now exist apply only to declared facilities and do not include procedures for seeking out clandestine facilities. Nor is it likely that international safeguards could feasibly be broadened to include such procedures.

Following receipt and review of this report, a series of questions requesting clarifications and addition to the report, focusing mainly on the classified portion, was submitted to ERDA. ERDA then prepared written answers to these questions. The ERDA response remain classified.

In addition, a classified meeting was held with ERDA, LLL, and LASL representatives to discuss all the material prepared by ERDA for OTA.

Appendix VII. Purchase and Theft

This appendix is largely based on a report to OTA from The Hudson Institute, "Routes to Nuclear Weapons: Aspects of Purchase or Theft," by Lewis A. Dunn, Paul Bracken, and Barry J. Smernoff, November 12, 1976.

Appendix VII

Purchase and Theft

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INTRODUCTION

A potential route to proliferation is by the direct acquisition of weapons or fissile material from abroad. This could involve purchase from an illegal black market, covert purchase or barter from a friendly nation in what is called grey market, or theft of another country's weapons. Each bypasses the need for the expensive and demanding technologies entailed by commercial power and dedicated facilities. Thus, if this type of transaction emerges, the scope of proliferation could be extended to technologically limited nations that otherwise have found the task difficult and risky. The pace of proliferation could be further accelerated by the relative ease of obtaining weapons, a general sense that the non-proliferation regime was crumbling and a specific concern that one's enemies were covertly obtaining weapons. In addition, this is almost certainly the route which non-state adversaries (NSA's) would have to follow. Hence this route has grave implications for the hopes of limiting proliferation.

1. Black Market

a. Commodities

A nuclear black market would center on the illicit exchange of fissile material, weapons designs or actual weapons. Most attention has focused on plutonium because under present plans for plutonium recycle, only a very small fraction would have to be diverted to fuel a very large market. As described in Section IV, the construction of a plutonium bomb is well within the capabilities of many nations and possibly some NSA's. An equally attractive commodity would be highly enriched uranium, as in the fresh fuel for high temperature gas cooled reactors. Other potential commodities such as low enrichment uranium used as fresh fuel for LWR's or spent fuel from almost any reactor would require much greater efforts to convert to

weapons material.

A black market might also involve a detailed design of an efficient bomb, which would reduce the time and risk to develop a weapon. NSA's capabilities and credibility would be particularly enhanced by a clever explosives design tailored to NSA construction capability.

Nuclear black marketeering could also entail the exchange of stolen nuclear weapons or fissile materials "mined" from such weapons. Particularly vulnerable targets of such thefts might be nations who have only recently acquired nuclear weapons. For political and technical reasons such countries may lack adequate command and control procedures for their nuclear forces and stockpiles.

b. Participants

Prospective buyers could include countries; subnational terrorist groups, and political or military factions; criminal groups; and perhaps even individuals. Each could have reasons for seeking access to nuclear weapons or their critical components.

Technologically limited but internationally ambitious countries might become active seekers of black market nuclear materials or bombs. Colonel Qaddafi's repeated efforts to purchase a nuclear weapon for Libya are well known.[1] Less well known, however, were the earlier comparable efforts of former President Sukarno to purchase a nuclear weapon for Indonesia from China.[2] A sudden crisis could also precipitate a desire for nuclear weapons without leaving time for their more conventional development. For example, if Israel reveals a nuclear arsenal, Egypt would be under great pressure to match it, but would not have the facilities or expertise to do so independently with sufficient speed.

Subnational groups of varying types also could emerge as buyers of stolen or diverted fissile materials or nuclear weapons if these became black market commodities. Much speculation has focused upon possible future efforts to gain

access to nuclear weapons by organizations such as the Irish Republican Army or the Palestine Liberation Organization (PLO) which consider terror a legitimate weapon. Appendix III deals with such subnational groups.

In a non-nuclear weapon state a faction of high-ranking military men or even a militaristic private army such as Yukio Mishima's now defunct group could engage in black marketing to acquire a nuclear weapon or its critical components to facilitate a coup.[3] Alternatively, such a group could conclude that their ability to unveil one or more nuclear weapons--whose acquisition would have been barred to the legitimate government perhaps due to external pressure--could turn out to be critical for national survival in a future crisis. The perpetrators might be largely motivated by a vision of their eventual emergence as national saviors.

Criminal groups--conceivably even individuals--might wish to acquire nuclear arms, most probably for extortion. Interest might be stimulated by the hoaxes in this vein that have been attempted (none successfully), as described in Appendix 111. A genuine explosive would not be hard to prove, and the ransom for its return could be sizable.

Corresponding to this variety of customers is a variety of potential suppliers whose identity depends on the commodity being marketed. Nuclear material might be diverted by a nuclear facility employee who is motivated by money, coercion, or ideology. This diversion could be gradual to avoid detection by safeguards measures or rapid and overt to permit escape. Terrorist and criminal groups could acquire fissile material by armed attack, especially on shipments of plutonium.

Nuclear weapons might be procured by theft, but the risk would be high even with insiders bribed or coerced to help. The tight physical security protection probably makes theft of weapons more difficult than that of commercial plutonium would be. The absence of attempts against American nuclear stockpiles

suggests that criminal organizations might shy away from such theft. Terrorist groups, however, might have greater motivation. If Nth country nuclear stockpiles prove somewhat easier targets or if the trade-offs among the risks and payoffs of such theft changed in the future, theft of weapons may occur. A more likely supplier of black market weapons--as opposed to gray market ones, where the government itself would be engaged--could be financially ambitious and dissatisfied officers within new nuclear-weapons states. These factors are discussed below.

A weapons design would most logically be supplied by someone in an existing weapons program. Relatively few designers have a comprehensive grasp of the entire design, however, and very few if any of these would be receptive to black market offers. Only if they were coerced or changed their ideology would they be likely to sell a weapons design illicitly.

If a transaction required an intermediary, likely candidates would be criminal groups (fences) or international terrorist groups. A distinction should be made between the emergence of intermittent transactions and the development of a full-blown market. intermediaries could be highly instrumental in the latter.

c* Characteristics

1. Factors Affecting Supply

Clearly no nuclear black market will develop unless material is available for diversion or theft and subsequent purchase via illicit channels. If fissile materials were freely traded in international commerce, scarcity would not be a significant constraint upon the possible emergence of such illicit transactions. More specifically, the extent to which various nations reprocess spent fuel and recycle plutonium will be the primary determinant of the magnitude of this international commerce. If, for example, plutonium is nowhere separated from spent nuclear fuel and recycled into light-water reactor fuel or stockpiled for breeder reactors, possibilities for its leakage onto a black market would be drastically reduced. Alternatively, if plutonium has become a normal international commodity in the sense that many countries

separate it from spent fuel for near-term recycle or future utilization in breeder reactors, the development of an illicit plutonium market, perhaps using some of the sources, distribution channels, and human resources of the legal plutonium market, would be more likely.

Projections for the amount of plutonium that could be reprocessed in the future are shown in Appendix IV. Large quantities are anticipated to be moving in international commerce in the 1980's. It is quite impossible to estimate accurately how much might be diverted or stolen, but a small fraction (e.g., 1%) would be adequate for a significant number of weapons and might sustain a continuous market rather than intermittent transactions.

Although plutonium, if recycled, would be the most tempting target, black marketeers might steal spent fuel and subsequently extract plutonium from it. This reprocessing would be done in clandestine national reprocessing facilities or hotcell laboratories run by sub-national or criminal groups. Once the fuel has cooled for 150-200 days in reactor spent fuel pools,

it can be handled with caution and could be diverted into illicit channels as a source of black market plutonium. Alternatively, if advanced uranium enrichment technologies such as gas centrifuge and laser isotope separation become widespread, low-enriched uranium could become a more attractive target for nuclear black marketeers. Both these alternatives would be limited to very sophisticated and well financed black marketeers

The potential supply of material for a black market depends upon the viability and effectiveness of safeguards and physical security measures for nuclear materials. Should a major safeguards agreement violation occur and not be met by an adequate response sufficient to prevent an erosion of the morale and effectiveness of International Atomic Energy Agency (IAEA) inspectors, the safeguards system could erode markedly. Countries might become less ready to cooperate with the IAEA, inspectors might become less willing to challenge possibly suspect activities, material accounting requirements might be followed less rigorously, and so on. Such a deterioration of the safeguards system's viability then not only might facilitate covert diversion by governments for their own purposes, but also could facilitate diversion by nuclear facility employees for black market sale. Conversely, an increase in the effectiveness of existing safeguards procedures and systems, reducing the level of material unaccounted for (MUF) in the nuclear fuel cycle and otherwise restricting unauthorized access to nuclear materials, would increase the obstacles to successful slow diversion and increase the risks of attempting it. Concomitantly,

new fuel-cycle protection systems - emphasizing, for example, better containment concepts, limited personnel access, and discrete storage of only small quantities of material - would have a similar dampening impact upon potential supply. Such increased safeguards' effectiveness would reduce the feasibility of "trickle theft" as a source of supply, just as enhanced physical security measures and high guard morale can reduce large-scale facility break-ins and hijackings.

The adequacy of physical security measures for nuclear weapons, of course, would be an important determinant of black market supply. Those measures are discussed below in the context of a consideration of nuclear-weapon theft. Suffice it to suggest here that it appears that sufficient supply to fuel a continuing market in stolen weapons - even Nth country ones - as opposed to one-shot ad hoc exchanges appears lacking.

2. Demand-Related

A second set of factors influencing the emergence and extent of marketeering would be the level of demand for illicit nuclear weapons or their critical components. The price buyers would be willing to pay --both financially and in terms of risks assumed--would vary, of course, with the perceived utility of the black market nuclear commodity, as described in Appendices I and III. As more customers are willing to pay higher prices, more sellers will run *greater risks to meet demand.*

Specifically, the possible impact of *regional* warfare, or even its prospect, might generate sufficient demand to induce widespread nuclear black marketing. Because the buyer would be anxious to build a large arsenal in a short time. The result could be the emergence of many

individual diversion activities, continuing networks and criminal organizations providing necessary middleman services. If Egypt, for example, suddenly needed an arsenal of about 20 bombs, the required 250 to 500 pounds of plutonium would in itself be a major factor. Plutonium is not freely traded at present, but its approximate value might be estimated at $9,000/lb. ($20/gram)*,indicating a total transaction of $2,000,000. The future price may well be much higher, and the black market price could be several times that. Egypt may still feel this is a small price under the circumstances, especially if financial assistance is obtained from the richer Arab countries.

The future scope and pace of nuclear proliferation could also be a major factor affecting demand for a nuclear black market. If in the 1980s-1990s a growing number of countries have begun to acquire nuclear weapons, proliferation momentum--the belief that widespread proliferation was becoming inevitable--would increase. Low-technology countries, who believe that their neighbors would “go nuclear” but are unable to develop a matching capability, might seek to redress the balance by black market purchases. Whether such countries actually pursued this course of action, however, also would depend upon the perceived risks and existence of alternatives.

Non-state adversaries are unlikely to be rich or powerful enough to generate a sufficiently large demand to foster more than intermittent black marketing even if the supply is sufficient. Nevertheless, only one successful application of a nuclear weapon by a NSA would encourage others to follow suit. The emergence of this demand is, however, even more conjectural than that by nations. As suggested in Appendix III,

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groups that have both the will and the ability to use nuclear weapons evidently do not yet exist.

3. Initiation

Transactions could be initiated by buyers, sellers or middlemen. Because participants are generally quite disparate groups, both contact and trust would be difficult to establish. A country seeking to purchase fissile material or weapons would probably first approach a friendly nation as Indonesia did with China (unsuccessfully) in the example above. Such a government-government deal would have been typical of a gray market transaction described below. If it fails, a government might try Colonel Qaddafi's approach of publicly announcing that it wanted to buy fissile material and waiting for a supplier to show up. (This method apparently has not worked yet either.) Alternatively, a country might try to make contact directly with potential suppliers or criminal middlemen. This method is quite risky if secrecy is required, however, as North Korea recently demonstrated in Scandinavia by its inept attempts to act as a black market supplier of liquor and tobacco.

Suppliers would probably more easily initiate contact since the buyers are fairly obvious. An employee of a nuclear facility who believed he could divert material might contact a foreign government or nationals or a criminal group which might be interested. To establish his credibility, a supplier might have to produce an initial sample.

Terrorist and criminal groups might easily make contact with **their counterparts who would procure or use the** material. Both have **international links and appear to be relatively** secure against **surveillance.**

The participants will weigh the risks and costs against the potential gain before entering into black market transactions. The risk

that a nation might be detected while purchasing the material is fairly high, but the costs are very low. Libya seems no worse off for Colonel Qaddafi's nuclear efforts. NSA's run lower risks of detection of attempted purchase, and if an analogy with the illicit drug trade is valid, they probably would not face serious consequences unless caught with a substantial amount of material after the purchase. A seller may be able to arrange the transaction relatively easily, but he runs a substantial risk of detection in the diversion and very high consequences if caught.

Weighed against these risks are substantial gains. If an employee of a reprocessing plant smuggled out one gram of plutonium per day (an amount invisible to most accounting systems and difficult for present portal monitors to detect), he should realize at least $5,000 per year and maybe much more. An attack on a stockpile or transport of plutonium could net several million dollars worth of material.

The initial incidence of nuclear black marketeering might be quite unpredictable and localized--both in terms of supply and demand--but once several successful black market transactions had been consummated, the demonstration effect could produce a slow broadening of the black market. Thus, a global black market to which potential proliferators and subnational groups might turn for illicit nuclear materials and expertise ultimately could result. Hence, one of the most important factors affecting the emergence of a black market is the perceptions of the potential participants of the likelihood and severity of the alternative responses which could range, for example, from pursuit and capture of organizations and individuals serving as suppliers to invoking severe punitive sanctions against a country that purchased stolen nuclear material or weapons.

4. Operation

The distinction between intermittent transactions and a sustained black market is essentially the difference between amateur and professional operations. The latter is far more dangerous, not just because it involves a greater material flow, but because it seeks to expand itself. Despite its size, detection and control of a sustained market might be more difficult because of the greater expertise of the participants, especially the suppliers and middlemen.

The level of potential activity clearly is bounded initially by supply availability, and most importantly by whether or not plutonium emerges as a standard international commodity. Within that constraint, the extent of nuclear black marketeering would be influenced by the interaction of demand and response factors. In particular, the only customers who would be likely to sustain a market are LDC's with strong incentives, especially security. Some of these might continue arming indefinitely.

These regular customers together with occasional purchases by other nations and NSA's could support a market of several hundred pounds of fissile material worth millions of dollars per year. Although small by comparison to the drug market, these transactions would have a large impact on proliferation. The market might consist of a number of suppliers possibly in different countries working through one or more central exchanges. Because fissile material is easily concealed and smuggled across national borders, all countries must carefully protect their supplies and respond strongly when they detect a loss . An efficient black market will select the weakest link as its target.

d. Conclusions

At present, the supply of fissile materials is highly limited but would increase with widespread plutonium recycle. The inherent lack of prestige of nuclear weapons attained by this route may inhibit some nations, but those with intense security concerns will feel few compunctions. A continuing pattern of proliferation could lead some countries to the conclusion that they too shall have a few nuclear weapons “just in case”. Safeguards and physical security cannot be perfect. Some diversions will succeed, and early successes will breed more attempts, particularly if the response is limited. Thus, if supply is not controlled, the outcome is likely to be at the very least intermittent black market transactions.

2. Gray Market

a. Definition

A gray market differs from a black market in that the transaction may be technically legal but is nevertheless covert because it would be unacceptable if known publicly. The main reasons for the secrecy would be to avoid alerting an enemy or to forestall international stigma from furthering proliferation in violation of the NPT. Some countries may also wish to bypass domestic opposition. If the non-proliferation regime crumbles so that secrecy is not necessary, the transactions described here could become normal commercial ventures.

The transactions could involve weapons or fissile material as in a black market or technical assistance. Examples of the latter are help with the construction of facilities for weapons production (e.g., plutonium reprocessing plant), transfer of critical weapon components, or exchange of information (designs) or trained manpower.

b. Participants

The buyer in a nuclear gray market could only be a government because purchase by any non-national group would be illegal and, therefore, by definition, a black market activity. The supplier could be an allied government, a corporation or an individual. There would probably be no intermediaries.

A future new nuclear-weapon state might send several of its own engineers and technicians to another prospective proliferator to assist the latter in developing, for example, a production reactor or hot-cell reprocessing capability; or it might supply needed components or raw materials for building or operating either facility. New nuclear-weapon states might find the reduction of the size and weight of their early generation nuclear warheads to be critical to improve deliverability. More advanced proliferators could assist others in

doing so by transferring design information and test results.

The direct transfer of fissile material (accompanied again by weapon-design assistance) or actual weapons is possible if the motivation is high. In some cases, unsafeguarded fissile material, derived from indigenously built production reactors could be exchanged. Another possible source of supply is material from power reactors unsafeguarded following abrogation of the NPT. The use of material diverted from safeguarded facilities is less likely as the risk is higher and the motivation for supplying another country substantially less than one's own.

Companies in the international nuclear industry are also capable of rendering considerable covert assistance. They would probably not offer fissile material but important proprietary information, such as details of plutonium reprocessing, would be of use to a potential proliferator. Alternatively, corporate-to-country transactions might involve the covert supply of necessary technical manpower, loaned to a proliferator's program and hidden within the framework of a continuing commercial presence in the recipient country.

Technically trained individuals could participate in a nuclear gray market by becoming scientific mercenaries, i.e., selling their services to a foreign government. Such individuals might be skilled either in plutonium reprocessing, weapons design or even in general explosives or metallurgical work.

c. Characteristics

1. Government-Government

No nation yet has shown a willingness to transfer nuclear weapons directly to another, but some might reconsider under some circumstances. A weapons state would feel great pressure to covertly release a few bombs to a close and valued ally which was on the verge of annihilation. Under less dramatic conditions, few governments would be willing to take a step potentially risky to themselves and so flagrantly in violation of international agreements. A country would be more likely to deal with fissile materials than bombs, because it could rationalize the exchange as being for scientific purposes.

Technical assistance is the most probable transaction. Most importing nations would prefer to have their own production facilities and thus a guaranteed continuous supply. Many circumstances can be envisioned that make it seem plausible. The supplier of a vital resource such as oil might demand assistance as part of a trade. If proliferation becomes commonplace, a nation might view its nuclear expertise as a "service good," as do the suppliers of conventional arms. Economic pressures and manpower constraints could also suggest a cooperative development program, which would have the added advantage of being less apparent to third party intelligence since neither nation need have the complete requisite set of facilities.

Pursuit of narrow political advantage also might lead a state to engage in gray marketing. For a hypothetical example, a future nuclear-armed Pakistan might see provision of technical assistance or sale of a nuclear weapon as one means of acquiring or solidifying Arab, or perhaps Iranian, political support in its confrontation with India.

Conversely, India might find itself ready to trade such assistance for Arab or Iranian non-support of Pakistan. Reciprocal fears in India and Pakistan that the other might be thinking about how to use its nascent nuclear-weapon potential as an export commodity would increase the pressure on each to do so first. "Preemptive gray marketeering" could be the result.

Broader international trends also could either increase or engender pressures for gray marketeering. If current developments continue, Israel, South Africa, and Taiwan may become increasingly isolated within the international community. Should they truly become threatened as international outcasts, they might join together in a "pariah international." Building upon and transforming existing linkages among them--e.g., South African-Israeli cooperation in the fields of advanced scientific technology, conventional arms, and perhaps nuclear undertakings and Taiwanese purchase of uranium from South Africa[4]--this group might give serious consideration to nuclear-weapon cooperation and transactions. If such a "pariah international "emerged, moreover, its existence and cooperation in nuclear matters might stimulate other countries to think about comparable gray market activities.

Some nations might see a need to acquire covertly a small stockpile as a deterrent before risking detection as a producer. For instances, a marked erosion of American alliance credibility could significantly increase West Germany incentives to acquire nuclear weapons.[5] Fear of the Soviets, however, might constrain that decision and perhaps lead first to West German efforts to develop a covert nuclear-weapon capability before launching a full weapons program. Such a capability to be unveiled suddenly might be though necessary and sufficient to preclude a Soviet preemptive attack. One possibility would involve a covert gray market joint

venture with either Brazil or South Africa. The extensive existing contacts between these countries might be used to hide the presence of illicit activities.

At least in the early stages of nuclear gray marketeering, the most likely sources of government-to-government technical assistance, fissile materials, or weapon-design information are likely to be the new nuclear- and candidate nuclear-weapon states themselves. Not only are the above discussed pressures likely to emerge, but countervailing pressures operating on the major nuclear suppliers as evidenced by the Suppliers Conferences are likely to be only weak constraints. Taken together, Tables 1-6 suggest the growing, if still limited prospective capability of such new nuclear- and candidate nuclear-weapon states to enter into gray market transactions among themselves or with even weaker candidate nuclear countries. More specifically, for many prospective early proliferators these tables depict: increasing potential access to separable plutonium; a growth of trained elite manpower represented by their students studying within the United States; a greater capability for indigenous training of technical manpower; the start of exports of engineering products by some of them; a shifting international market for engineering products which again includes the emergence of some LDCs as not insignificant engineering exporters; and a growing consumption of engineering products, itself indicative of growing momentum behind the development of a technological infrastructure in many of these countries.

The pattern of engineering and industrial activity within less developed countries is indicative of their capability to utilize gray market transactions. Many have demonstrated a marked capability to adapt used machinery to specific purposes, to make do with what is available, and more generally to fabricate "jerry-built" operations that highly industrialized countries would consider totally inadequate for the task at hand. The Indian plutonium reprocessing plant was just such a jerry-built affair, adapting and combining equipment available from disparate sectors of the Indian economy.[6]

2. Corporation-Government

International nuclear corporations are less probable participants. Recent revelations of corporate bribing of foreign officials[6] give rise to speculation that this form of gray market assistance could occur, but it must be noted that only an exceptionally unscrupulous executive would authorize such a transaction. Not only would most find the idea abhorrent, but exposure of the transaction would have a devastating impact on the company. If a company has a large investment in another country, however, it could be placed under considerable pressure to provide assistance. If this could be done in such a way that the assistance appeared directed towards peaceful purposes, the initiation would be easier.

It is also not inconceivable that some companies could eventually use their expertise in pursuit of commercial advantage or even as an article of commerce. The likelihood of this happening would be enhanced if the nuclear activities of international corporations are constrained in their home countries.

The major nuclear companies are described in Appendix VIII. In general, the types that might be considered are reactor manufacturers, architect-engineers and consulting companies. If peaceful nuclear explosions are commercialized, companies dealing with them might be technically appropriate.

3. Individual-Government

Scientific mercenaries could emerge from the growing pool of nuclear industry and weapons personnel. The global nuclear industry by itself will require approximately 115,000 trained engineers in 1980.[8] Thus, a sizable pool of scientific and technical manpower, some of whom would be conversant with plutonium reprocessing, materials handling, and related fuel cycle technologies, can be expected to exist. Within the major industrialized nuclear suppliers there exists a group of professional nuclear scientists and engineers whose careers have been tied to the prospect of future plutonium reprocessing. If reprocessing is banned or severely limited in these countries, the combination of career shock and economic necessity might tempt or force some of these people to seek plutonium-related employment in other countries. Nuclear moratoria or even just lagging sales could add appreciably to the number of potential mercenaries. Precedents for the migration of

skilled manpower to nations with higher demand exist in the brain drain of earlier decades as shown in Table 7 . Migration to an LDC may seem less attractive than to a developed country and most individuals would feel a strong aversion to contributing to proliferation, but even a very low percentage of the whole pool could have a substantial impact on the rapidity of a weapons development program.

Of even greater value to a fledgling Nth country's weapon program would be individuals who had worked within the nuclear-weapon program of one of the existing nuclear-weapon countries. Depending upon such persons' level of expertise and prior responsibilities, this pool of potential nuclear mercenaries could number from tens to thousands. Even though virtually all of these persons would likely refuse any offers to sign on as scientific mercenaries, some might do so, especially under duress. Even one or two expert weapons designers can be crucial to some countries.

One factor that will work against these transactions is the desire of nations to keep their program a secret. The loyalty of foreigners in this situation is somewhat questionable, and the duration would generally be too long to keep a team sequestered voluntarily.

4. Precursors to Gray Market Activities

In the Fall of 1975, several European newspapers and magazines published "secret" documents supplied by the African National Congress and alleged to have been stolen from West German ministries and from the South African Embassy in Bonn, suggesting covert semi-official and private West German involvement in South Africa's development of uranium enrichment technology. These documents revealed the growth

after 1958 of extensive contacts between various West German semi-official bodies, e.g., the state-controlled fuel company STEAG, West German ministry members, and private West German companies and both the South African Atomic Energy Board and the South African Uranium Enrichment Corporation. Of particular interest was a letter dated July 12, 1972, from the West German State Secretary at the Ministry of Education to the president of the South African Atomic Energy Board referring to the secrecy of any West German participation in South African atomic energy matters. The Bonn Government maintains that "all speculation about cooperation between the two governments is unfounded,"[9] but both the fact that West Germany's representative to the NATO Military Affairs Committee, Lieutenant General Gunther Rail, was forced to resign in 1975 after these documents revealed he had clandestinely visited South Africa as a guest of its Defense Ministry in October 1974 and the similarity between the West German "Becker nozzle" uranium enrichment process and the South African "jet nozzle" process suggest that some, perhaps extensive, cooperation may have occurred.[10]

Other possible precursors of government-to-government gray marketeering include the training of Egyptian scientists at the Indian Bhaba Atomic Research Center at Trombay,[11] and reports of South African-Israeli nuclear cooperation, including the purported existence of a secret nuclear test center in South Africa at which technicians and scientists from Israel are supposedly working.[12]

d. Conclusions

Gray market transactions appear to be at least as likely as black market transactions. There are already potential suppliers for at least some types of assistance, and it is entirely possible that some examples

have already occurred.

Thus potential supply may be a less critical impediment to nuclear gray marketeering than to black marketeering. In particular, the increasing accumulation of plutonium-bearing spent fuel and the growing technological and manpower base of many prospective proliferators probably would suffice to permit them to enter into gray market transactions with other countries. At the same time, a growing pool of potential nuclear mercenaries, comprised of former nuclear weapons designers and technicians, surplus engineering manpower, and unemployed nuclear engineers, is not unlikely.

A major constraint is the difficulty of establishing trust. A criminal group might sell to anyone who could pay, but a nation would only assist a country whose political outlook and interests were compatible with its own. Thus a formal structure such as postulated for the black market is unlikely, and transactions would be on an individually negotiated basis.

Some black market characteristics, however, do have relevance. The demand motivations are approximately the same, but most nations would certainly prefer dealing with other nations and legitimate sources than black market operators. Both markets become far more likely if proliferation continues, and both will be encouraged if the international response to initial examples is weak. Finally, both would even further accelerate the pace of proliferation.

3. Countermeasures to Black and Gray Markets

a. Detectability

The first step in combating black and gray markets is to detect them. There are two general focal points: the participants and the

material. Intelligence gathering operations can serve to indicate who is participating in such transactions. The greatest difficulty will be to distinguish these from legitimate transactions. By way of illustration, the inflow of engineering talent to the oil-producing countries, the growth of world trade in engineering products, and the even faster growth of multinational corporations stimulate migration of highly trained technical manpower to a vastly greater degree than would any gray market. Penetrating this noise is nevertheless one of the keys to controlling the problem, and success will depend largely on the quality of the effort applied.

One potential difficulty with such intelligence gathering and storage, however, should be noted and ways of reducing its impact sought. Some of these measures, e.g., computer-storage of dossiers on former nuclear-weapon designers or nuclear engineers with critical skills, as well as efforts to track their movements, probably would conflict with important civil liberties. Additional detailed analysis of the potential civil liberties spillover of different intelligence measures and of the relative weighting of each case would appear warranted.

The second focal point basically means safeguards to detect when material has been diverted. The same considerations apply as for

national diversions, except that the function of the person who actually diverts and the route by which the material leaves the authorized location is likely to be different.

Both these methods can be enhanced and reoriented towards this threat. Increased effectiveness in detection would be a potent deterrent to potential participants.

b. Responses

Once an effective intelligence program is established, the information would be useful for adopting preventive measures, for taking prior counter-action in the case of unconsummated transactions or plans, and for responding afterwards in an attempt to limit the damage already done. To the extent feasible, intelligence data should be pooled among countries committed to non-proliferation.

A second realm of responses, particularly in relation to possible black market theft or diversion of fissile materials or nuclear weapons, would entail target-hardening. Recent and projected efforts to increase the rigorousness of physical security systems within the nuclear industry would fall under this category. So would measures designed to increase safeguards viability and effectiveness. As suggested earlier, however, such measures, taken alone, appear unlikely to be able to preclude the emergence of at least some instances of nuclear black marketeering.

Perhaps most important, a broad range of politico-military responses can be identified. Possible responses might include a readiness to adopt sanctions against countries engaged in nuclear gray marketing

police work to capture black marketeers, control of the activities of potential nuclear mercenaries and corporations abroad.

In addition, serious consideration should be given to reducing more directly the potential supply of black or gray market nuclear materials. Arrangements to limit national proliferation would generally be effective against black and gray markets. In particular, measures to avoid the emergence of plutonium as a freely-traded international commodity could be pursued. Some of these measures, such as multi-national fuel cycle facilities, would be more effective against gray than black market diversion.

There is obviously no certainty that these transactions will emerge, but plausible situations have been described. Strong responses could reduce their likelihood and limit their growth past initial sporadic examples.

4. Theft of Nuclear Weapons

a. Potential Attackers

The range of groups that could consider an attack on a nation's nuclear weapons stockpile or transport is much narrower than that of black market suppliers described above. Only highly motivated and well organized and armed groups could have much chance of overcoming effective military security precautions surrounding the weapons. Potential attachers include low technology nations, military factions and terrorist groups. Criminal groups probably have as great a capability as terrorist groups, but the near certain violent resistance and post facto reactions to a theft are strong deterrents. Criminals' motivation is financial rather than ideological, and equally profitable but less risky ventures are available to them.

The prospect of a successful theft is a powerful incentive. Theft is the most direct route to a nuclear weapon, and would probably result in a more sophisticated and effective weapon than obtainable by other routes,

b. Theft of U.S. Weapons

1. Description

It has been publicly reported that the U.S. has several tens of thousands of nuclear warheads with approximately 7,000 of these in Europe and a classified number in the Pacific Ocean area.[13] U.S. naval vessels also carry them. The warheads are used in bombs, missiles (land, air and sea launched), artillery shells, depth charges, torpedoes, and demolition charges. Some of these, such as demolition charges are small enough to be easily carried by one person. Artillery shells can be carried by two people, but are normally stored in packing cases which require four. Others, particularly those used in strategic weapons, are much larger.

All nuclear weapons have built-in protection against unauthorized use. A weapon must be armed manually with a coded key before it can be fired. Even then some can be fired only under certain conditions. For example, nuclear artillery rounds might contain built-in accelerometers that fully arm the shell only after detecting the very high acceleration that would accompany. normal firing. Such devices can be bypassed eventually. Hence, Permissive Action Links (PAL) were developed. These devices permanently but nonexplosively disable a weapon if it is tampered with. This key element of the physical security system is incorporated in all newer U.S. weapons abroad. The weapon may, of course, be rebuilt following activation of the PAL, but the delay would enhance the chances of recovery, and the rebuilt weapon would probably suffer a loss in efficiency. It could still be a highly effective weapon, however.

Whatever the technical value of these safety devices, however, the political value may be small. Informed that a terrorist group had stolen an A-bomb, the public would be hard to convince that the problem was minimal because of certain technical control devices of the particular model. Even if political leaders are convinced that these technical characteristics would prevent detonation, public pressure could induce political leaders to capitulate to the terrorist demands.

2. Physical Security

Weapons are generally kept at special storage sites except for naval weapons on board ships at sea. The number and location of storage sites are not publicly reported, but there has been a trend to consolidate them to improve physical security. During 1974 and 1975, there was a net closure of 97 nuclear sites. A countervailing pressure, however, is the need to maintain security against destruction by a military attack.[14]

The sites are usually on military installations, isolated and surrounded by fences. The perimeters are monitored automatically and patrolled continually. Backup forces are available on short notice. The weapons themselves are kept in vaults.

These measures are significantly more stringent that is required for commercial fissile material, but they are recognized by the Department of Defense as being inadequate in light of the increasing threat from terrorists. Approximately $230 million is budgeted for FY76-77 to upgrade security at storage sites. This is being spent in part on training of

security personnel, improved perimeter sensors and lighting, additional guards, hardening of facilities and better communications. A psychiatric evaluation program (Nuclear Weapon Personnel Reliability Program) has also been instituted to identify and disqualify troubled personnel who might be receptive to approaches by would-be attackers seeking inside help.[15]

Transport is a weak link in the physical security system. It is, however, relatively infrequent except during alerts. Transport is generally accomplished by an escorted armed helicopter. Flights are unannounced and do not follow regular routes. Continual radio contact is maintained with the base and a contingency response is on alert.[16]

Some transport is intrinsic in the mode of use. Ships and submarines regularly carry many warheads. Bombers fly with the weapons only during alerts.

3. Attacks

No determined attacks on nuclear storage sites have been revealed to date. Several other examples, however, do show the difficulty of defending against well trained commando raids. Otto Skorzeny in 1943 led an assault party of only ten to fifteen in gliders on a mountain fortress to free Mussolini. In this case, the subject of the raid was eager to be liberated and the defenders mostly fled at the sight of the attackers, but in 1944 Skorzeny led another raid which is even more pertinent. He kidnapped Admiral Horthy, the Hungarian regent, by penetrating the Hungarian presidential palace which was surrounded by tanks and infantry.[17] More recently, the Black September

penetration of the 1972 Munich olympic compound, the North Korean capture of the Pueblo and Israeli raid on Entebbe are examples of the types of attacks to be considered.

Conclusions can be drawn from a study of such cases, as described in Appendix III. In attacks on nuclear storage sites, very small groups (l-4) are unlikely to gain entrance. Groups of 5-8 attackers may have a chance of gaining control of the site, but would have considerably more trouble removing the weapons. Larger groups (8-20) would more likely be effective in achieving their objectives. An imaginative approach, diversionary tactics and the cooperation of one or more insiders naturally increases the probability of success. Intelligence activities, however, are more likely to detect such large groups in time for reinforcement of defenses.[18]

Massive attacks such as the Entebbe raid, which are essentially acts of war, are least likely to be resisted successfully, but neither can they be accomplished anonymously. Consequently, political and military responses, if activated, should be expected to ensure return or destruction of stolen weapons. An appropriate military response was unavailable when the Pueblo was seized because of the ship's isolation. This should not be a factor in attacks on storage sites.

Attacks on transports would be hard to plan because the opportunity is not presented often. Insiders would almost certainly be required to provide information as to when opportunities will occur. Both air and ground forces would probably be needed. Thus in terms of manpower, financial backing and skill, this is probably equivalent to the groups of 8-20 above. The probability of success, however, may be higher.

Attacks on bombers, ships and submarines are the least possible. Nuclear weapons are no longer carried by planes on routine missions, but only on alerts. Naval vessels are heavily armed and difficult to approach unless aground or suffering mechanical difficulties. Thus assuming reasonable precautions are taken regarding routes and distance from assistance, only a large amount of luck would put these weapons within reach of attackers.

Some U.S. nuclear weapons are for the use of other NATO countries. These weapons are guarded by the host country although custody is maintained by small U.S. detachments. A sudden change in governments could leave these weapons highly vulnerable. Even U.S. storage sites in foreign countries would be much less secure following a sudden violent change in government. These weapons would have to be rapidly removed, a process which in itself would increase their vulnerability because of the predictability of the flights, the difficulty of mounting an effective response to an attack and the probable loss of most intelligence sources.

c. Theft from Other Present Nuclear States

The USSR and the People's Republic of China are probably relatively immune to externally mounted attack because of the nature of these societies. An Entebbe type of attack on the PRC might be considered by its neighbors, but the risks and problems would be great.

The United Kingdom and Franc probably have far fewer nuclear weapons than the U.S. has in Europe. Most or all of these are kept on national territory, further reducing the risk. There appears to be no reasons to think that security over these weapons is less stringent than that of the U.S. since their safeguards on commercial fissile material seem to be comparable to that in the U.S. Security sources

have suggested, however, that some of the hardware such as PAL's and perimeter sensors may not be as sophisticated as those of the U.S. forces.

do Theft from Nth Countries

If proliferation continues, opportunities for theft will arise in the new nuclear states. It is, of course, impossible to predict with a high degree of confidence, how tight the security would be in these Nth countries. Some potential Nth countries have experienced turbulent domestic politics, including military interventions. This will increase the pressure for tight control to avoid losing the weapons to military factions and other non-state adversaries, and thus as a side effect to external attackers. Some nations, however, may lack the sophistication to develop devices such as PAL's. Their control mechanisms would consist of means such as leaving the weapons disassembled and the parts separately protected. This will decrease operational readiness and, therefore, military effectiveness Insecure nations may prefer, therefore, to risk unauthorized access. Another problem, though less likely, could be a general unwillingness to worry about physical security. The U.S. has gradually upgraded its protection level as appreciation of the magnitude of the growing threat increased. Nth countries may be slower in coming to this view, especially since good security is expensive.

One other potential threat is that of a military faction stealing their own weapons and black marketeering them. If security is lax and control not strictly organized, this could be fairly easy to do.

TABLE 1 SEPARABLE PLUTONIUM WITHIN RESEARCH AND POWER REACTOR SPENT FUEL

COUNTRY	ACCUMULATED (KG) OF SEPARABLE PLUTONIUM						ANNUAL PRODUCTION (KG) SEPARABLE PLUTONIUM					
	1974	1979	1984	1989	1994	1999	1974	1979	1984	1989	1994	1999
ARGENTINA	0	350	1,228	4,089	7,340	10,066	0	70	334	598	598	598
AUSTRALIA	11.9	15.4	18.9	22.4	25.9	29.4	.7	.7	.7	.7	.7	.7
BELGIUM	3.7	4.7	5.7	6.7	7.7	8.7	.2	.2	.2	.2	.2	.2
BRAZIL	0	85	866	7,101	16,874	26,619	0	113	329	1,715	1,949	1,949
CHILE												
CUBA												
DENMARK	9.9	13.2	16.5	19.8	23.1	26.4	.7	.7	.7	.7	.7	.7
EGYPT	0	0	216	1,836	3,456	5,076	0	0	108	324	324	324
GREECE												
INDIA	402	1,032	2,424	4,204	6,009	7,814	117	213	361	361	361	361
INDONESIA	0	0	216	2,592	5,202	7,812	0	0	108	522	522	522
IRAN	0	0	1,242	5,022	29,502	53,982	0	0	594	756	4,896	4,896
ISRAEL	18.7	27.2	33.7	648	1,188	1,728	1.7	1.7	1.7	108	108	108
ITALY	935	1,941	6,099	26,024	45,929	65,834	90	243	931	3,981	3,981	3,981
JAPAN	1,460	10,126	26,585	43,705	60,855	77,945	694	2,528	3,424	3,424	3,424	3,424
LIBYA												
NIGERIA												
NORTH KOREA												
NORWAY	26.5	35.2	43.9	52.6	61.3	70.0	1.8	1.8	1.8	1.8	1.8	1.8
PAKISTANM	64	201	605	1,405	2,205	3,005	28	28	160	160	160	160
PHILIPPINES	0	0	226	1,356	5,006	12,076	0	0	226	226	730	1,414
RUMANIA	0	0	316	1,791	3,266	4,741	0	0	79	295	295	295
SAUDI ARABIA												
SOUTH AFRICA	0	0	513	2,220	3,930	5,640	0	0	342	342	342	342
SOUTH KOREA	0	281	1,951	8,457	15,287	22,117	0	102	650	1,366	1,366	1,366
SPAIN	588	2,613	12,192	18,636	32,101	66,446	165	1,133	2,333	2,693	2,693	6,869
SWEDEN	212	3,169	10,654	20,589	30,524	40,459	228	962	1,987	1,987	1,987	1,987
SWITZERLAND	622	1,617	6,366	12,271	18,221	24,171	181	347	1,011	1,190	1,190	1,190
SYRIA												
TAIWAN	5.3	206	1,961	6,241	11,198	15,478	2.7	206	856	856	856	856
TURKEY	0	0	0	540	1,080	1,620	0	0	0	108	108	108
VENEZUELA												
WEST GERMANY	1,657	7,621	21,6$3	42,782	62,697	82,612	376	2,067	3,212	3,983	3,983	3,983
YUGOSLAVIA	9.9	13.2	915	2,370	3,825	5,280	0.7	0.7	291	291	291	291
ZAIRE												

SOURCES: DERIVED FROM PAN HEURISTICS, MOVING TOWARD LIFE IN A NUCLEAR ARMED CROWD?, PREPARED FOR THE U.S. ARMS CONTROL AND DISARMAMENT AGENCY, ACDA/PAB-263, APRIL 22, 1976 AND ATOMIC INDUSTRIAL FORUM NEWS RELEASE, "NUCLEAR POWER-PLANT COMMITMENTS OUTSIDE THE U.S. CLIMB17% IN YEAR," WASHINGTON, JUNE 2, 1976.

TABLE 2

FOREIGN STUDENTS IN THE UNITED STATES

COUNTRY	1972-1973		1973-1974		1974-1975
	TOTAL	ENGINEERING	TOTAL	ENGINEERING	TOTAL NON-IMMIGRANT
ARGENTINA	702	77	703	67	560
BRAZIL	1,560	266	1,713	258	1,970
CHILE	870	154	997	150	950
EGYPT	1,148	335	1,163	302	980
INDIA	10,656	4,615	10,168	3,912	9,660
INDONESIA	695	151	768	139	1,080
IRAN	7,838	3,744	9,623	4,393	13,780
IRAQ	361	103	376	93	420
ISRAEL	2,113	486	2,070	488	2,390
LIBYA	573	187	690	242	980
PAKISTAN	2,690	1,291	3,301	1,339	3,140
SAUDI ARABIA	943	297	1,074	300	1,540
SOUTH AFRICA	418	43	403	39	510
SOUTH KOREA	3,730	757	3,612	669	3,390
SPAIN	612	98	630	79	580
TAIWAN	9,633	2,676	8,416	2,018	10,250

SOURCE: OPEN DOORS, 1973,1974, 1975; INSTITUTE OF INTERNATIONAL EDUCATION.

(1) ESTIMATES FOR 1972-1973 AND 1973-1974 INCLUDE IMMIGRANT STUDENTS.
(2) COUNTING PROCEDURE SIGNIFICANTLY MODIFIED FOR 1974-1975 ESTIMATES PROVIDING A MUCH GREATER ACCURACY IN COUNT; EARLIER YEARS INCLUDED FOR ILLUSTRATIVE PURPOSES.

TABLE 3

INDIGENOUS TECHNICAL MANPOWER PRODUCTION (1)

POTENTIAL NTH COUNTRIES	ANNUAL OUTPUT (OF EARLY 1970s) NATURAL SCIENCE	ENGINEERS	TOTAL
Algeria	315	94	409
Argentina	617	2,486	3,103
Australia	4,704	3,288	7,992
Brazil	6,092	8,129	14,221
Chile	189	1,840	2,029
Cuba	350	646	996
Egypt	7,627	1,085	8,712
Greece	1,919	825	2,744
India	67,546	18,090	85,636
Indonesia	140	1,120	1,260
i ran	2,693	3,734	6,427
Iraq	'1,305	1,069	2,374
Israel	1,378	1,003	2,381
Italy	8,214	5,727	13,941
Japan	11,031	79,638	90,669
Libya	73	88	161
Nigeria	156	60	216
North Korea	NA	NA	--
Pakistan	5,746	1,169	6,915
Phillippines	1,431	4,256	5,687
Rumania	2,705	7,743	10,448
Saudi Arabia	73	82	155
South Africa	NA	NA	--
South Korea	2,968	10,080	13,048
Spain	2,657	6,332	8,989
Sweden	1,971	1,944	3,915
Switzerland	1,015	784	1,799
Syria	438	300	738
Taiwan	MA	NA	--
Turkey	2,081	3,797	S,878
Venezuela	71	664	735
West Germany	5,199	20,771	25,970
Yugoslavia	1,614	6,679	8,293
Zaire	78	71	149
Total	142,396	193,594	335,990

SOURCE: UNESCO Statistical Yearbook 1974, Table 5.3.

(1) THIS DATA REPRESENTS PRODUCTION OF COLLEGE LEVEL ENGINEERS. IT NEGLECTS INDIGENOUS EDUCATION OF TECHNICIANS AND ENGINEERING SUPPORT PERSONNEL.

Table 4

TRADE IN ENGINEERING PRODUCTS
1974
(IN MILLIONS OF U.S. DOLLARS)

BRAZIL	SOUTH AFRICA	9.5
	LIBYA	2.1
	ARGENTINA	52.3
	CHILE	25.5
	IRAN	1.2
	ISRAEL	.9
	SAUDI ARABIA	3.1
	INDONESIA	1.8
	SOUTH KOREA	.3
	PAKISTAN	.1
	SPAIN	1.8
	TURKEY	.1
SOUTH KOREA	SOUTH AFRICA	.2
	LIBYA	1.1
	ARGENTINA	4.0
	BRAZIL	.4
	CHILE	.2
	IRAN	1.3
	SPAIN	.2
	TURKEY	.1
	YUGOSLAVIA	.4
INDIA	SOUTH AFRICA	.1
	LIBYA	2.0
	IRAN	6.8
	SAUDI ARABIA	1.8
	INDONESIA	2.8
	SOUTH KOREA	.4
	YUGOSLAVIA	3.7
ISRAEL	SOUTH AFRICA	3.1
	ARGENTINA	.3
	BRAZIL	.1
	IRAN	21.9
	SOUTH KOREA	1.3
	SPAIN	.8
	YUGOSLAVIA	.1

Table 5

GROWTH IN THE WORLD TRADE OF ENGINEERING PRODUCTS
(IN CURRENT U.S. DOLLARS)

	REGIONS OF ORIGIN	
	DEVELOPED MARKET ECONOMIES	DEVELOPING COUNTRIES
1963	$ 31.0 BILLION	.2 BILLION
1965	39.2	0.3
1970	78.4	1.0
1971	91.1	1.3
1972	108.4	1.9
1973	142.0	3,2
1974	179.0	3.4

SOURCE: BULLETIN OF STATISTICS ON WORLD TRADE IN ENGINEERING PRODUCTS, Economic COMMISSION FOR EUROPE, UNITED NATIONS, E/F/R.76.11.E.7, 1976. TABLE 1A, PAGE 20.

Table 6

TRADE IN ENGINEERING PRODUCTS
(1974 TRADE IN MILLIONS OF U.S. DOLLARS)

SOURCE / DESTINATION	UNITED STATES	SOVIET UNION	WEST GERMANY	FRANCE	ITALY	UNITED KINGDOM	CANADA	JAPAN
ARGENTINA	192.9	1.9	146.3	51.6	92.5	42.9	25.9	55.6
BRAZIL	1,298.0	8.6	702.1	141.6	181.8	146.4	38.1	577.6
CHILE	139.8	---[1]	59.0	28.9	8.9	22.9	19.0	22.2
EGYPT	55.5	165.2	83.6	42.2	29.2	58.2	2.1	31.2
LIBYA	65.5	2.0	247.4	248.3	255.0	80.9	4.7	143.4
SAUDI ARABIA	424.2	1.2	177.9	50.9	57.7	135.3	9.8	298.8
INDIA	127.5	107.1	173.8	54.8	26.6	168.4	15.2	151.0
INDONESIA	236.7	5.1	200.5	61.6	29.5	64.3	8.8	602.3
PAKISTAN	145.8	14.8	58.2	28.9	20.0	66.1	8.6	98.0
SOUTH KOREA	367.8	---	90.5	24.4	11.4	70.2	7.8	1,046.5
IRAN	570.4	217.0	658.4	114.6	165.9	317.3	18.2	196.8
SOUTH AFRICA	547.5	---	839.7	202.9	193.4	652.2	39.0	455.6
IRAQ	123.6	120.3	252.8	91.9	46.4	64.9	1.1	95.9
SPAIN	584.9	3.3	840.7	464.5	385.5	230.9	29.4	114.0
ISRAEL	351.0	---	232.5	86.0	76.5	110.9	6.9	21.3
TURKEY	191.7	36.7	390.7	102.1	179.7	149.2	21.5	73.5
YUGOSLAVIA	141.1	110.8	740.2	132.7	324.3	105.5	7.9	24.4

[1]---INDICATES MAGNITUDE ZERO.

[2]DATA FOR TAIWAN NOT AVAILABLE FROM UNITED NATIONS SOURCES.

SOURCE: BULLETIN OF STATISTICS ON WORLD TRADE IN ENGINEERING PRODUCTS, 1974, UNITED NATIONS, ECONOMIC COMMISSION FOR EUROPE, E/F/R.76.11.E.7, NEW YORK, 1976.

Table 7

PRECEDENTS FOR THE MIGRATION AND MOBILITY OF TECHNICAL MANPOWER

	ENGINEERS	NATURAL SCIENTISTS
TO UNITED STATES, 1962-1966, FROM DEVELOPING NATIONS	19,055	7,793
TO UNITED STATES, 1972, FROM TAIWAN; INDIA, PAKISTAN, AND SOUTH KOREA	3,716	1,371
TO ISRAEL, 1967-1968, FROM UNITED STATES*	~3,000	

*OF WHICH THE NEW YORK TIMES [FEBRUARY 28, 1972, PAGE 2] SAID "... IS QUIETLY EMERGING AS ONE OF ISRAEL'S MOST IMPORTANT NATIONAL ASSETS FOR DEVELOPING THE COUNTRY'S LONG-RANGE POTENTIAL."

SOURCE: BRAIN DRAIN: A STUDY OF THE PERSISTENT ISSUE OF INTERNATIONAL SCIENTIFIC MOBILITY. PREPARED FOR THE SUBCOMMITTEE ON NATIONAL SECURITY POLICY AND SCIENTIFIC DEVELOPMENTS OF THE COMMITTEE ON FOREIGN AFFAIRS, U.S. HOUSE OF REPRESENTATIVES, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, SEPTEMBER 1974.

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12. Far Eastern Economic Review, September 10, 1976.

13. Joint Committee on Atomic Energy, 'development, Use and Control of Nuclear Energy for the Common Defense and Security and for Peaceful Purposes," Second Annual Report, July 19, 1976.

14. Ibid.

15. Ibid.

16. Personal communication with LTC. Richard W. Martin (DNA).

17* William L. Shirer, "The Rise and Fall of the Third Reich, Simon and Schuster, New York City, 1960.

18. Briefing by Defense Nuclear Agency, December 7, 1976.

Appendix VIII. Description of Safeguards Technology and Procedures

First Draft by Science Applications, Inc.

Revised and Expanded by OTA Consultants

Appendix **VIII**

Description of Safeguards Technology and Procedures

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1. Introduction

This report supports OTA's ongoing assessment of nuclear proliferation and safeguards (1)* by providing a technical background on the systems and procedures which exist in the U.S. today and on the U.S. program to provide improved methods and procedures. Although the focus of the OTA study is on the international proliferation of nuclear weapons technology and nuclear weapons, domestic safeguards systems are relevant because each nation must protect its nuclear materials from non-national groups which might use such materials to threaten that nations society or threaten other nations. The U.S. safeguards programs are relevant insofar as they may contribute to the reliability of safeguards systems in other nations and provide direct or indirect support to the IAEA.

In the U.S., there are three major nuclear programs and three agencies having safeguards responsibilities. The three programs are: military, nuclear power, and nuclear research. The Department of Defense provides the safeguards for the nuclear weapons in its possession. The Energy Research and Development Administration (ERDA) operates production facilities for the nuclear military programs and conducts research on nuclear power and other non-military nuclear applications. The Nuclear Regulatory Commission (NRC) is responsible for applying safeguards to privately owned nuclear facilities and to a few ERDA-owned facilities (waste storage and power reactors feeding public electric power grids) . Major ERDA and NRC facilities are listed in Tables 1 and 2.

Some idea of the types and amounts of nuclear materials presently possessed by private organizations and under NRC safeguards may be derived from the following.

For uranium (2)*:

Dec. 31, 1975 Licensee Ending Inventory by Enrichment Range

Enrichment Range	# of Locations	Element Weight	Isotope Weight (U-235)
less than 5%	133	8,541,225 kg	166,282 kg
5% to 20%	72	2,168	226
20% to 80%	42	1,660	1,054
"over 80%	138	34,379	33,435

*(Ref. 1: See Reference List at end of Appendix VIII.)

*(Ref. 2: J. Inst. Nuc. Mat. Management, Special Report, Aug., 1976, p. 44)

Table 1.1

Major Government Owned, ERDA Facilities

Military Applications	Production	Research
Los Alamos Scientific Lab.	Union Carbide GDP, Oak Ridge	Oak Ridge National Lab., Tenn.
Lawrence Livermore Lab.	" " " , Paducah, Ky.	Argonne National Lab., Ill.
Sandia Laboratories	Goodyear GDP, Piketon, O.	Brookhaven National Lab., L.I.-N.Y
Rocky Flats, Colorado	Atlantic Richfield, Hanford, Wash.	Aerojet Nuclear, Idaho
Union Carbide, Y-12, Oak Ridge	Du Pont, Savannah River, S.C.	Hanford Engineering Development Lab., Wash.
Mason & Hanger, Tex.	Idaho Reprocessing Plant	
Monsanto Mound Lab., Ohio		
Nevada Test Site	GDP = gaseous diffusion plant to enrich uranium	
G.E. Knolls Lab., N.Y.		
Westinghouse Bettis Lab., Pa.		

Table 1.2

Major Privately Owned Nuclear Facilities Subject to NRC Regulations

Nuclear Power Plants

Built: 59

Being Built: 73

Planned 6/30/76): 79

Research Reactors

Total: 68

Containing more than 5 kg of high enriched uranium: 16

One megawatt or higher power: 23

Critical Assemblies

Containing more than 5 kg of high enriched uranium: 5

Misc. R&D

Licensed for more than 5 kg of high enriched uranium: 5

High Enriched Uranium Fuel Fabrication

Babcock and Wilcox, Apollo, Pa. (Naval Fuels)
Babcock and Wilcox, Lynchburg, Va. (Naval Fuels)
Nuclear Fuel Services, Erwin, Tenn. (Naval Fuels)
United Nuclear Co., Uncasville, CN. (Naval Fuels)
United Nuclear Co., Wood River Jct., R.I. (scrap rec.)
U.S. Nuclear, Oak Ridge, Tenn. (research fuels)
Texas Instruments, Attleboro, Mass. (research fuels)
Atomics International, Calif. (research fuels)
General Atomics, San Diego, Cal. (H.T.G.R.)

Low Enriched Uranium Fuel Fabrication

General Electric, Wilmington, N.C.
Westinghouse, Columbia, S.C.
Combustion Engineering, Windsor, Conn.
Babcock & Wilcox, Lynchberg, Va.
Exxon Nuclear, Richland, Wash.

Plutonium Fuel Fabrication

Babcock & Wilcox, Leechburg, Pa.(1)
General Electric, Pleasanton, Cal.(1)
Westinghouse, Cheswick, Pa.(2)
Exxon Nuclear, Richland, Wash.(2)
Nuclear Fuel Services, Erwin, Tenn.(2)

(1) ERDA fuels or R&D

(2) small or no operations

Fuel Reprocessing

None operable

Notes on Table 1.1:

LASL, LLL, Sandia, Rocky Flats, Y-12, Mason and Hanger have substantial amounts of HEU*, Pu or both.

Mound Lab. processes Pu-238.

The Nevada Test Site has weapons occasionally, for Tests.

Knolls and Bettis have modest amounts of HEU for R&D.

The OR and Padukah GDP's produce only LEU.*

Goodyear GDP produces HEU for HTGR's, research reactors and military applications.

Atlantic Richfield, Hanford processes and stores Pu.

The Savannah River reactors produce Pu, Pu-238, etc.

The Idaho Chemical Processing Plant, reprocesses HEU fuels from research and naval reactors.

Argonne National Lab., West (Idaho) should be added to the list of research facilities. The SSNM at research facilities is primarily for or in reactors.

Note on Table 1.2:

As of 6/30/76, 59 power reactors had been built
57 power reactors were operable
73 power reactors were under construction
79 power reactors were planned

***HEU:** Highly-enriched uranium

***LEU:** Low enriched uranium

For uranium and plutonium[3]*:

> **"There** are sixteen licensees in the private sector who are authorized to possess strategic quantities of plutonium and high-enriched uranium. These kinds of special nuclear material, if stolen in sufficient quantities, could be fashioned into a crude nuclear explosive, if the thieves had the requisite technical skill and equipment.
>
> The greatest percentage of this high-enriched uranium is government-owned and is being processed in licensed facilities for national security programs. High-enriched uranium for commercial purposes (about six percent of the total quantity in the private sector) is mostly in storage vaults and is likely to stay there unless additional high temperature gas-cooled reactors are built and operated. A small amount of high-enriched uranium is being used to fabricate research reactor fuel.
>
> About half of the plutonium in commercial plants is government-owned. Certain licensed facilities process plutonium for development programs related to the liquid metal fast breeder reactor. Otherwise, the material is being used in small quantities for R&D purposes or is in vault storage. Thus, the amount of special nuclear material, plutonium and high-enriched uranium, being used outside national security programs is very small and at this time is largely in vault storage."

*(Ref. 3: Kenneth R. Chapman, Director Nuclear Material Safety and Safeguards, NRC to Natural Resources Defense Council, Mar. 22, 1976.)

The total amount of plutonium in the private facilities is probably less than 1,000 kg at this time. There are between 1,000 and 1,500 shipments per year of significant amounts of high enriched uranium, plutonium or U-233. Less than 100 of these are shipments of privately owned nuclear materials.

In view of the several Government and private nuclear **pro-**grams, it is useful to identify those which relate to national defense and those which pertain to civil applications. The former activities are classified in the interest of national security; the latter, generally, are not. The overall assessment of the benefits of a national military nuclear program relative to the safeguards risks of theft or diversion is different from such an assessment for non-military nuclear programs. From the point of view of proliferation, it is the nuclear power program and the R&D programs of both ERDA and NRC that are relevant.

The future course of nuclear power in the U.S. is being reviewed. The questions being publicly debated are whether or not to authorize private construction of uranium enrichment plants, private reprocessing plants, fabrication of mixed uranium-plutonium fuels for recycle in light water reactors and whether or not to proceed with the liquid metal cooled fast plutonium breeder program.

In view of this situation, the present safeguards systems described below are designed principally to protect Government owned nuclear materials. These systems have been significantly upgraded in recent years and are still in the process of review and improvement. The safeguards programs of ERDA and NRC are especially important for assessing the future safeguards risks which future nuclear energy choices might involve.

2. Domestic Safeguards in the Mid 1970's

2.1 Purposes and Objectives and their Application in the U.S.

In the international sense, "Safeguards" has heretofore implied the use of inspection and material accounting techniques to provide assurance that nuclear material has not been diverted to weapons programs; physical protection of the material is treated as a separate issue. In the domestic context "safeguards" are more broadly defined as "all measures designed to detect, deter, prevent, or respond to the unauthorized possession or use of significant quantities of nuclear materials through theft or diversion; and sabotage of nuclear facilities." Hence domestic safeguards covers both physical protection and material control and accounting. Thus, the overall international and domestic 'safeguards" systems are concerned with comparable elements to attain similar but not identical objectives. A discussion of safeguards modes of operation and likely effectiveness is most usefully started with a consideration of purposes, implementation and regulation of safeguards in the U.S. In this chapter, we will be concerned with today's approach.

Note: IAEA safeguards pertain to 'control of and accounting for nuclear materials" supplemented by measures of containment and surveillance. Although the IAEA cannot assume responsibility for physical protection, it does recommend physical protection methods to member states.

The objectives of safeguards have been stated in several ways, for example:

"Safeguards measures are designed to deter, prevent, or respond to (1) the unauthorized possession or use of significant amounts of nuclear materials through theft or diversion; and (2) sabotage of nuclear facilities. The safeguards program has as its objective achieving a level of protection against such acts (as) to insure against significant increase in the overall risk of death, injury, or property damage to the public from other causes beyond the control of the individual-''(4)*

*(Ref. 4: Draft GESMO, WASH-1327, Aug. 1974, p. V-6)

An ERDA statement(5)* is:

'Specifically, the objectives of ERDA's integrated Safeguards and Security plan are to:

"1. Prevent successful malevolent acts involving nuclear materials or facilities, so as to protect the public against risk of death, injury, and property damage that could arise from such acts;

*(Ref. 5: See next page.)

"2. Protect classified information from authorized disclosure; and,

"3, Protect Government property from Theft or malevolence."

(Ref. 5: Master Plan , ERDA Div. of Safeguards and Security, ERDA-76/122 (Sept. '76], p.5)

Reference 6*, a report of a group of NRC consultants, expands on these generic statements and indicates how the safeguards system may be defined:

"It is clear, at least within the context Of Civil order, that safeguards should be designed to prevent major disasters involving the use of nuclear materials and facilities. In addition, they should provide protection against serious incidents having adverse societal impacts. The requirements for safeguards become less clear at the lower levels of consequences, where misuse of nuclear material or facilities may constitute only a bothersome incident. Safeguards should protect the public from harm, but not necessarily prevent every conceivable incident. Lower thresholds of consequences, in terms of the significance of potential damage or the amounts and quantities of materials involved, can be used to identify one limit on the scope of safeguards."

'Limitations on the upper levels of threat, with which the safeguards system must cope, can be derived from the presumption of civil order. Within any given context of time, place and societal behavior, responsible police and intelligence organizations should be able to assist in defining the size and quality of threats that might emerge, with and without warning, to perpetrate malevolent acts involving nuclear materials and facilities. In the case of external threats, this definition might be of numbers of people and the quality of their arms and material and their training and tactics. In the case of internal threats, it might be of numbers of conspirators and their level of authority within the industry. Thus, the scope of both internal and external safeguards can be bounded-on the lower side in terms of the consequences of of the acts involved and on the upper side in terms of the credible threats that can be postulated within a context of civil order. This defines the breadth of the safeguards program. "

*(Ref. 6: A Report to the U.S. Nuclear Regulatory Commission on a "Conceptual Approach to Safeguards," 31 October 1975. Prepared by a group of NRC-sponsored consultants for the Division of Safeguards. U.S. NRC)

'Both physical protection and material accounting and control must be configured so that, at and above the consequence level at which disasters can occur, the combination of an active safeguards program (within the bounds of a credible threat) and contingency planning (extending beyond credible threats toward the realm of civil disorder) is sufficient to preclude any major disaster."

2.2 Elements of the U.S. Safeguards Systems

The sub-objectives of U.S. safeguards systems (of NRC, ERDA and the Dept. of Defense) are: (1) to deter hostile acts, (2) to prevent attempts to steal nuclear materials or to commit acts of nuclear sabotage, and (3) to minimize the consequences if the previous efforts should fail. The following discussion relates primarily to the second item, to the safeguards measures intended to block adversary attempts. An obviously strong preventive system will serve to deter most potential adversaries. Legal penalties for misuse of nuclear materials, also may serve as a deterrent. An example of a measure to minimize consequences would be the use of radiation detectors to detect the presence of plutonium, where it might be dispersed after having been stolen, so that people could be evacuated from a building or an area before they have inhaled damaging amounts.

Deter: Persuade potential adversaries that attempts to steal or to sabotage nuclear materials will not be successful or useful in achieving their ends. Deterrent activities include: (1) A system of safeguards in-depth that appears to offer little chance of success to the adversary, (2) condign punishment, if apprehended, (3) rewards for, information leading to conviction for attempted hostile acts. This offers a counter incentive to accepting bribes, and threatens to reveal conspiracies, (4) a public and government resolve to prevent development of a black market, so that individuals who might steal nuclear materials have no way to benefit from such acts.

Prevent: Ideally a safeguards system should absolutely prevent theft or sabotage. No system is perfect. But safeguards can and

should be designed to interrupt any conceivable adversary action plan at a number of points so that the chance of completing his mission is vanishingly small. Since certain skills, knowledge and resources are required to steal nuclear materials, to fabricate a nuclear explosive, to disperse plutonium or to sabotage, e.g. a nuclear power plant, a properly designed safeguards system would aim to interrupt the sequence of adversary steps starting with the initial planning and going all of the way to minimizing the consequences, should the scenario proceed to the final stage. For analysis, it is useful to treat the recovery and response stages separate from those which are normally considered as preventive measures.

In as much as there are many conceivable action plans for outsider adversaries, insiders, and combinations thereof, the strategies for interrupting them should also be varied. In general, the earlier steps should aim at anticipating an adversary action. Intelligence agencies could be alert to discover nuclear conspiracies. Personnel reliability programs could aim to identify authorized personnel who may require special attention. Information which might reveal just where nuclear materials are accessible or the specifics of plant physical protection systems could be withheld from the public-at-large. The material control, material accounting and physical protection measures outlined in the Code of Federal Regulations are intended to place multiple barriers in the way of potential adversaries.

Recover: Even if nuclear materials should be stolen, it might still be possible to locate the thieves before they could make use of them. Experts do not agree on how long it might take to fabricate and to place a nuclear explosive, but it would take from days to

many weeks. ERDA and DOD have developed radiation detection instrumentation to make area and localized searches for stolen weapons and weapon materials (there is some more information in the Master Plan). If the theft were announced, one could count on the public to report suspicious activities for investigations. Plans could be made to search for inadvertent leaks of radioactivity or for deliberate dispersal.

Minimize consequences: This subject should be a part of national plans to respond to serious threats to the public health and safety. Equally serious threats could arise from natural causes, industrial accidents, or terrorist acts involving non-nuclear materials or facilities. It is a complicated subject because there are many conceivable emergencies. For example, in the case of the Legionnaires Disease, it was not clear whether the agent was a virus, a chemical, or whether it was a chance occurrance or a deliberate act. Credible hoaxes, nuclear or otherwise, present especially difficult problems. A panic reaction could cause as much death and destruction as the threatened event itself.

The general structure of national safeguards systems are described in two pamphlets which were written by experts from member nations for The International Atomic Energy Agency, These are: "States System for Physical Protection of Nuclear Materials" (INF/CIRC-225) , and "States system for Control of and Accounting for Nuclear Materials" (IAEA-AG-26). The three basic elements are: physical protection, control of the nuclear materials and accounting procedures. "The general composition of each of these is as follows: (1) physical Protection comprises personnel reliability determinations and all of those measures related to access controls, physical barriers, penetration alarms and to armed protective response and recovery forces; (2) material control procedures are those which are provided to maintain continuous surveillance of the nuclear materials and of the personnel who have access to them; and (3) accountability procedures involve the measurement of materials received or shipped out of a facility and of materials transferred within a facility; the maintenance of books and records giving the location of nuclear materials and the amounts; and the taking of complete physical inventories at intervals in order to determine whether or not the book inventories are correct."*

*(Ref.: ERDA DSS Master Plan ERDA-76/122 (Sept. '76), p. 9)

The physical protection sub-system should prevent access to the materials in a plant or shipment by force, by stealth or false identity. It should prevent surreptitious-removal of nuclear materials and respond to internal attempts to divert or to sabotage equipment. The physical protection-sub-system overlaps the material control sub-system designed to detect any unauthorized or suspicious activity involving the nuclear materials. Present day accountability systems provide primarily for a determination, after some period of time, that the other two sub-systems have been effective or to provide information as to where and how they may have failed. Additionally, such information may detect continuing small diversions and-provide information useful for recovery operations. Highly automated semi-continuous measurement systems are under development which will provide prompt information that something may be missing.

The system, as a whole, should be an optimum combination of these facility sub-systems together with intelligence activities to help to anticipate adversary attempts and plans for a national response to hoaxes or to an actual theft or act of sabotage. The responsibility for intelligence gathering is assigned to the FBI and to other law enforcement agencies. NRC and ERDA have a primary role in assessing threats and hoaxes. Many Federal, state and local agencies would be involved in responding to credible nuclear threats.

2.3 Current US-Nuclear Regulatory Commission Safeguards

The basic documents defining the nature and extent of nuclear safeguards are in Title 10 of the Code of Federal Regulations (10 CFR). The first, Part 70 of 10 CFR, describes procedures and methods of material control for SNM. Similarly 10 CFR Part 73 covers the physical security requirements for protecting special nuclear material and related facilities and activities. Together, these two regulations form the regulatory framework for all safeguards.

Complementing these two regulations are a series of Regulatory Guides. Here the focus tends to be more specific with an emphasis on how regulations can and should be implemented.

The regulatory requirements are different for reactors, for facilities that process low enriched uranium, and for facilities that process high enriched uranium or plutonium. Material control and accounting requirements for reactors are minimal. Reactor management is required to submit a physical security plan for NRC approval which satisfies the

requirements described-in Regulatory Guide 1.17 (on-site armed guards, alarms and redundant communications with local police). More extensive requirements for physical protection have been issued for comment, but not yet put into effect.

Both low enriched and high enriched uranium production facilities are required to meet the material control and accounting requirements discussed more fully below. No special physical protection requirements are placed on the low enriched uranium facilities. However, detailed physical protection requirements are given in 10CFR73 for shipments of strategically significant amounts of nuclear material and for production facilities having high enriched uranium and plutonium in more than threshold amounts.

The reasons for the difference in treatment are that low enriched uranium is not very radioactive nor can it be used as a nuclear explosive. Plutonium is produced in reactors but the hot spent fuel from reactors is extremely radioactive and hardly an attractive target for subnational subversives. It is important to maintain accountability of low enriched uranium in the interest of international control of nuclear materials and because quantitative measurement of the low-enriched fuel fed to a reactor provides one part of the data needed to determine how much plutonium is produced as the fuel is burned-up. Reactors need physical protection because they might be targets for sabotage. Facilities that process high-enriched uranium or plutonium obviously require both physical protection and material controls.

There are two papers on material accounting for low-enriched uranium: (1) A study that the Brookhaven Technical Support Organization made for NRC-MCSS and (2) A study by a special committee of the Institute of Nuclear Materials Management.*

U.S. industry maintains that the detailed material control and accounting requirements of 10CFR7O are unnecessarily burdensome for facilities with LEU, because LEU is not very radioactive (i.e., not a target for dispersal), and because it is not credible that U.S. terrorists would enrich LEU or use it to make Pu in a secret reactor. There are some crude estimates of the economic costs which could be saved by a relaxation of these requirements in Ref. 1.

Neither reference presents an adequate analysis of the international considerations. The IAEA is supposed to monitor all of the activities of a "state"" It starts with U_3O_8 prepared to enter the fuel cycle. IAEA will need reasonably good data on low-enriched fuel fabrication facilities in order to do an overall analysis of all of the nuclear materials flowing within a state. Accurate data on the uranium content and isotopic composition of the fresh fuel shipped to reactors is especially important to confirm the burnup-data from reactors and the amount of plutonium that should be recovered by reprocessing.

*(Ref. 1: "A Review of The Regulations Concerning The Control and Accounting of Nuclear Material" BNL-TSO, July 16, 1976)

*(Ref. 2: INMM - August 1976)

Actually, the conclusion of these references does not appear to be inconsistent with the needs of the IAEA.

The Brookhaven study concluded that MC&A requirements for facilities fabricating LEU fuel could be relaxed somewhat. It also concluded that MC&A for natural uranium should be increased.

The following discussion relates to the material control and accounting and the physical protection requirements now applied by NRC to the facilities that process high-enriched uranium or plutonium, i.e., spent fuel reprocessing plants and plants that manufacture fuels containing high-enriched uranium, plutonium, or U-233.

The regulations require that an organization establish a safeguards department which is independent of the production department, in order to obtain a license to possess and process special nuclear materials (enriched uranium, plutonium, etc.). The independent safeguards line organization is responsible for establishing material control and physical protection procedures and for enforcing them. NRC inspects the facilities to insure that the organizational structure and the procedures conducted comply with the requirements of the regulations and the specific safeguards conditions attached to each license.

Physical Protection at Fixed Sites

Regulation 10 CFR Part 73 treats physical protection in terms of 3 major groups of safeguards measures.

1. Barriers, intrusion alarms, portal controls, and surveillance to detect, and possible delay, (a) entry of unauthorized personnel and contraband and (b) unauthorized removal of SNM.

2. Alarm station, command post and communications to coordinate and direct the armed facility guard force and, when appropriate, to call for assistance from local law enforcement authorities.

3. Armed facility guard force to neutralize threats.

For example, fence, wall, floor and ceiling barriers are separately defined in terms of minimum dimensions and materials, guards are required to be uniformed and armed (guides recommend how they be trained) , the acceptable qualities of locks are specified as are materials for vaults.

Any facility is assumed divided into a hierarchy of **zones,** corresponding to the material, equipment or activities contained in each viz:

- Protected Areas: The overall plant region enclosed by barriers and having its access controlled.

- Vital Areas: Regions where equipment whose failure could endanger the public health (e.g., standby power supplies) is housed.

- Material Access Areas: Parts of a facility containing SNM.

Figure 2.1 shows in a schematic fashion the major components of a physical protection system for a fixed site.

The function of the fixed site physical protection elements described in the regulations are:

1. At least two physical barriers protect vital equipment and the special nuclear material (SNM) .

2* **Access** to the protected area is controlled by a system of coded badges. Access to the vital areas and material access area is by means of special authorization. Vehicles used primarily for the conveyance of personnel are not allowed in the protected area.

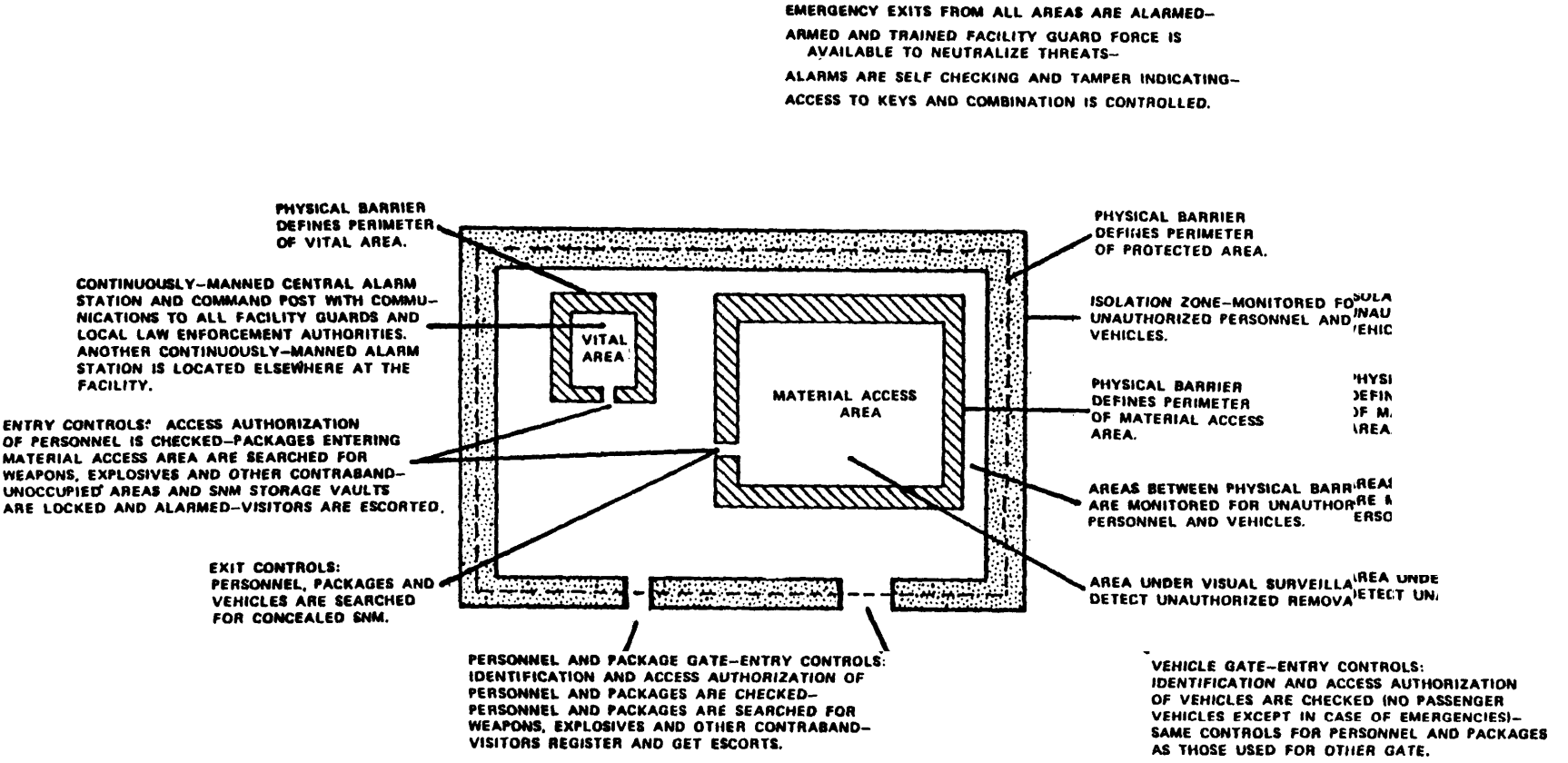

Figure 2.1 Physical Protection Requirements

3. At the protected area entrance, personnel and vehicles are searched for firearms, explosives or incendiary devices. All hand carried packages are searched. Other packages entering the protected area are searched at random.

4. Upon exiting a material access area, all personnel, Vehicles and packages are to be searched for concealed SNM.

5. Emergency exits of material access and vital areas are alarmed. Isolation zones and protected area barriers are monitored. All alarms annunciate in a continuously manned central alarm station within the protected area. A redundant continuously manned alarm station is also required.

6. Licensees must establish liaison with local law enforcement authorities, and be prepared to take immediate action to neutralize threats to this facility, either directly or by calling for local law enforcement authorities.

Material Control and Accounting

The physical protection systems, described above are designed to control the materials and the personnel entering or leaving the sensitive areas within nuclear facilities where vital equipment is located and where nuclear materials are stored or utilized. The material control and accounting systems are designed to detect diversion of SNM or sabotage attempts by personnel who have been authorized to enter the vital and material access areas. The 'material control" subsystem is intended to detect attempted diversion or sabotage promptly, so that such attempts can be interrupted. up to this time, the material accounting operation has been employed primarily to determine, after the fact, whether or not all the materials which should be on hand are still there - the classical role of accounting. In the future it will be possible to measure material in vaults and material being processed on an essentially continuous basis, so that any theft or diversion should be detected in time to take remedial action. This highly automated, measurement and accounting system is described in Section 4.4 of this Appendix.

The material control subsystem is intended to prevent any single individual from diverting nuclear materials from storage or from processing by requiring that at least two individuals observe any transfer of SNM. Operations personnel will request that SNM be transferred from storage to a process, from one

process to another and to storage. Each such internal transfer must be authorized by responsible management personnel and approved and witnessed by safeguards personnel. Every internal transfer is recorded on internal transfer documents, with copies for safeguards and for operations. These two independent sets of records should be compared frequently so as to insure that the records have not been compromised. A second level of control is applied at the perimeter of the material access areas by the physical protection system described above. Individuals entering or leaving must pass through radiation detectors (personnel monitors) which can detect small quantities of SNM; packages are searched and authorized SNM removals are to be certified by guards and health physicists, as well as by operating and MC&A personnel. The system is intended to prevent diversion from the facility by two "insiders" in collusion.

The material accounting system is presently similar to that employed for any type of highly valuable material. It is based on measurements of the amounts of material received, material shipped off-site and of all internal transfers (material may be sealed in containers, so that repeated measurements are not required unless a seal shows signs of tampering) . All measured amounts are recorded in ledgers and on transfer documents (frequently the records system employs computers). At intervals, specified in the regulations, the plant is shut down, the processing equipment cleaned out, and a physical inventory is taken. The materials found on inventory are compared to the amounts expected to be on hand and any significant discrepancy is investigated.

The materials involved at a processing plant may be in many different forms: liquid solutions, powders, pellets, rods, contaminated liquids or powders, pellets rejected for not meeting specifications, and low-level disposable wastes, such as contaminated clothing, equipment or cleaning solutions. A variety of measurement techniques are employed. Unlike most other industries, it is necessary to measure the isotopic composition of the SNM as well as the amount of uranium or plutonium.

The licensee is required to determine by measurement, the nuclear material content of all receipts, shipments, discards, and material on inventory. A description of the various measurements and measurement uncertainties that are used in nuclear material control must be provided. Error models based on statistical methodology and techniques are required to demonstrate the licensee's capability to meet adequate material balance criteria.

This description of MC&A is based on a BNL-TSO paper* prepared for the NRC Special Safeguards Study.

It is probably an overstatement to say that "the system is intended to prevent diversion by two insiders." It would be more honest to say that the degree to which this system might prevent diversion by two or more authorized personnel is not presently clear. Although it would appear to have the potential to require collusion by three for diversion, its effectiveness depends on the interpretation of the regulations by NRC licensing and inspection and by facility operators. Until this system is submitted to rigorous assessment, e.g., by diversion path analysis, as operated at actual facilities, the effectiveness will remain unknown, as would suggestions for modifying it.

***REF:** Limitations on Personnel Access to SNM Records, NRC-Special Safeguards Study 'by Brookhaven National Lab. , Technical Support Organization. Nov. 10, 1975.

Adequacy criteria and frequency for material balances are established by regulation and specify that the uncertainty in the material unaccounted for (LEMUF)* does not generally** exceed the limits in Table 2.1 for the frequency given. The ability to detect diversion via a material balance cannot, however, be inferred directly from these criteria because of a dependence on plant flow or throughput and the statistical nature of the test. For example, the criteria in Table 2.1 means a material balance uncertainty of approximately 0.5 kilograms of plutonium for present day plutonium fabrication plants with a throughput of 600 kg per year but an uncertainty of 75 kilograms of plutonium for a large reprocessing plant with a throughput of 15,000 kg per year. More specifically, a material balance discrepancy is called when a larger quantity of material appears to be missing than can reasonably be expected when the measurement uncertainties are taken into account. Current procedures are to call a discrepancy in such a way that in the absence of any diversion or procedural error, the normal uncertainty in measurement will give rise to a false alarm in one occasion in 20. Some small fraction of the LEMUF could obviously be removed without a significant increase in the probability of calling a discrepancy and an analysis of this issue is given in Annex A. For fixing ideas on how large a theft might be feasible it is useful to think in terms of:

a. A theft of 25% of the LEMUF being hard to detect. The probability of a discrepancy being called is one chance in ten.

b, A theft of 50% of the LEMUF being an upper bound of the credible “theft within the LEMUF". There is (approximately) one chance in five of its being called.

In this light the diversion of only 0.12 to 0.25 kg of plutonium per accounting period is credible in the example 600 kg/yr fabrication plant, while 20 to 40 kg Pu could possibly be diverted without detection in the 15,000 kg/yr reprocessing

*The material unaccounted for (MUF) is the measure of a material balance and is equal to the (beginning inventory plus receipts] minus the (ending inventory plus shipments]. The uncertainty in MUF is given in terms of a quantity called the limit of error of MUF or LEMUF and in the U.S. is twice the standard deviation in the measured MUF.

**These limits may not apply to small facilities with LEMUF less than 200 grams of plutonium or 300 grams of high enriched uranium, nor to facilities that can demonstrate inability to meet these limits after reasonable efforts have been made.

Table 2.1

Material Type	LEMUF* on Any Total Plant Inprocess Material Balance (expressed as a percentage of additions to or removals from material in process, whichever is greater)	Frequency of Material Balance
Plutonium element or uranium-233 in a chemical reprocessing plant	1.0%	6 months
Uranium element and fissile isotope in a reprocessing plant	0.7%	6 months
Plutonium element, uranium-233, or high enriched uranium element and fissile isotope - all other	0.5%	2 months
Low enriched uranium element and fissile isotope - all other	0.5%	6 months

*LEMUF is the measurement uncertainty component used in constructing a 95% confidence interval associated with a quantity after any recognized bias has been eliminated or its effect accounted for. Assuming a normal error distribution the LEMUF corresponds to a two-sigma discrepancy in the material balance.

plant. * Thus, regulatory limits on material balance uncertainty and frequency may translate into a capability to detect a weapon quantity of material diversion for present day plants but a significant improvement will be required to achieve this same detection ability for future large facilities.

NRC & ERDA support R&D to improve this situation. In the meantime the primary safeguards measures to prevent or to detect diversion are those of physical protection and of material control. Although accounting may not be very useful for prompt detection at large throughput facilities, it serves the following important functions: (1) it can provide information on whether or not the material control and physical protection have been effective; (2) in case they have not, accounting by material balance area should indicate where weakness exists and controls should be improved; (3) if some materials should appear to be missing, the type, amount, location and responsible individuals could be identified, and (4) good material accounting procedures may be the best way to detect continuing, low-level diversion.

Material accounting is an essential element of the overall safeguards system which is of special interest to plant management and to NRC inspectors for monitoring safeguards performance, as well as for manufacturing process control and company financial purposes. The combination of material control, material accounting and internal and external physical protection must be considered in designing and evaluating safeguards for SNM at actual facilities.

2.4 Physical Protection for SNM in Transit

Presently NRC & ERDA require physical protection of shipments of "strategically" significant amounts of SNM, i.e., more than 5 kilograms (kg of high-enriched uranium, or 2 kg of plutonium or U-233. Until recently, ERDA-owned materials, as well as privately owned, were transported by private transport companies which met the then existing security requirements. In 1976, ERDA decided to provide a secure transportation system for its nuclear materials, including high enriched uranium fuels for Naval reactors and research and plutonium fuels for the test breeder program. In consequence, all ERDA shipments of such significant amounts of nuclear materials between its facilities, private contractors licensed by NRC, and ERDA and private facilities, are now protected by the ERDA system, while the relatively few shipments of such privately owned materials are subject to NRC regulations.

*Note, this discussion is only relative to material accounting and not to physical protection or material control.

The NRC regulations, published in 10CFR73, place responsibility for protection of shipments on the licensed facility which makes the shipment, whether in its own vehicles or by contract with commercial shippers. The regulations require that shipments by truck must be dedicated, in the sense that the shipment should be door-to-door with no intermediate stops to transfer other packages. The truck should have a driver and a guard and the truck must be accompanied by an escort vehicle with two armed guards or the truck must be especially designed to resist penetration, etc. The truck, and/or escort, must be equipped with radio telephones for frequent communications or the convoy must phone-in every 2 hours.

Shipments of this size are now no longer allowed on passenger aircraft. Shipments of plutonium in cargo aircraft are forbidden until NRC has determined that safe shipping containers have been developed and proven. Any transfer from one mode of transport to another must be monitored by an armed guard. There are similar provisions regarding shipment by rail or ship (the subject of export, import and of foreign shipments which cross U.S. territory, is under review at this time) .

The ERDA secure transportation system was developed several years ago to transport nuclear weapons and weapon materials. Its principal elements are secure vehicles (tractor-trailers and railroad cars) , escort guards and a nationwide communications system. The tractor cabs are securely built to provide protection to the drivers/guards. The trailer, which carries the nuclear materials is designed to delay penetration by sophisticated adversaries for an hour or more. The tractor-trailer can be immobilized so that hi-jackers can’t tow it away. The tractor and the escort vehicle maintain continuous communication by short range radio and one or both are connected to the ERDA Transportation communications network, based in Albuquerque. The Albuquerque station monitors all shipments on the road, advises the vehicles as to weather and other hazards, and has an up-to-date list of state and local law-enforcement agencies along the routes. Similar protection and communications are provided for ERDA shipments by rail.

2.5 DOMESTIC SAFEGUARDS OUTSIDE THE U . S ,

During the performance of the present work, literature on safeguards of other countries was reviewed, and informal contacts were made. The countries included Canada, West Germany, the UK, France, Sweden and the USSR. Very little specific information was obtainable from the published literature. informal contacts may be summarized as follows:

1. Material Accounting: All countries claim capabilities to meet at least IAEA accuracies; there are also several developments (W. Germany and France) on real time accounting.

2. Physical Protection: No details of any system are available (on security grounds?). There are verbal claims that local experience (e.g., in France during the Algerian war) has stimulated the development of highly effective systems.

3. INTERNATIONAL SAFEGUARDS AND PHYSICAL SECURITY IN THE CONTEXT OF U . S . EXPORTS

The basis for the licensing of exports of nuclear material and nuclear fuel facilities to any given country is normally a tripartite "Agreement of Co-operation" that has been negotiated by the State Department and ERDA, the country in question, and the IAEA. Such agreements have been written for terms ranging from 10 to 50 years and cover a broad span, including general conditions for co-operation, fuel trade framework where applicable, and safeguards conditions. These "Agreements for Co-operation" set the framework (5, 6, 7)* for the NRC to issue general export licenses for commercial organizations to trade in both "source material" (natural uranium and thorium and their ores) and in special nuclear material (plutonium, U-233 and uranium enrichment) .

The process of export trade in nuclear materials and facilities begins with an application from the commercial vendor to the NRC for a license to proceed with a proposed transaction. The NRC in turn asks the Executive Branch for "information to assist in a determination of whether issuance of the license in question is consistent with U.S. national security".

Quoting from Ref. 8*(GAO's 1976 report)

> "The NRC then considers this information, together with data developed by its staff, in deciding whether to issue a license. NRC independently verifies some, but not all, of the information provided. For example, an NRC official told us that agreements for cooperation are examined to ensure that the export will be under appropriate safeguards and that on occasion additional information on physical security precautions had been requested.
>
> "NRC believes that, although it must rely heavily on the information provided in the Executive branch position paper, this is a proper procedure since those involved agencies are able to make integrated policy evaluations concerning international relations and

*(See Reference List at the end of this Appendix.)

national defense. NRC officials believe it is impractical for them to develop an independent capability for collecting and validating similar information solely for nuclear exports."

According to ERDA's recent Statement on U.S. Nuclear Power Export Activities (ERDA 1542, Ref. 7,) minimum requirements set by the Executive branch are now:

1. That recipients apply IAEA safeguards on nuclear exports from the U.S. This includes facilities and certain equipment as well as special material.

2. Extract assurances from recipients not to use these exports to make nuclear explosives for any purpose.

3. Application by recipients of adequate physical security to exports to deter theft and sabotage, (which supplements existing policy requirements regarding significance of sensitive materials)

4. Assurances from recipients that they will also require the above conditions on any-retransfer of these exports of transfers of material or equipment derived from the original transfer.

3.1 MATERIAL CONTROL AND ACCOUNTING REQUIREMENTS APPLICABLE TO EXPORT LICENSING REVIEW

As noted in the above requirements, the application of IAEA safeguards standards is now mandatory, and according to ERDA 1542 has been called out in all agreements concluded since 1968. Hence much of the safeguards information reviewed by the NRC will be that of the agreement between the receiving nation and the IAEA; this information will normally conform to the guidelines set forth in IAEA publication INFCIRC153 [9]

The present IAEA system is summarized below:

1. Design Review - Nations supply the IAEA with design characteristics, specifically material flow and handling and material control and statistics. The IAEA reviews these characteristics. This information is submitted in a standard format prescribed by the IAEA.

2. Records - The plant operator maintains records to account for all transactions with nuclear material based on measurements. These records are open to review.

3. Reports- The nation reports to the IAEA the amount of nuclear material at each plant and transactions that have occurred since the last report. The IAEA maintains its own accounting records of national inventories.

4. Inspection - The IAEA performs on-site inspections based on independent measurements to verify that records and reports are correct.

The IAEA system is therefore based entirely on verification of plant material control and accounting systems. The IAEA is concerned with two questions regarding material control and accounting:

1. Is the material control and accounting system adequate?

2. Do the records and reports adequately represent the plant's material status?

The first of these questions are asked during the design review performed by the IAEA, where plant characteristics, material handling procedures, and the measurement and accounting system are checked for adequacy. The second question can only be addressed through site visits by IAEA inspectors. Here the inspectors first verify that all records and reports are correct or estimate proper corrections, and second evaluate the material control status, i.e., the material inventories and the material balance uncertainties.

The step-by-step approach used by the inspector is grouped as follows:

1. Verification of item identification (using records and reports supplied by the facility as a reference)

2. Semi-quantitative measurement to detect:

   a. a. Gross defects (complete removal from an item)
   b. b. Medium sized defects (partial removal from an item)

3. Accurate quantitative measurement to detect:

   a. Inflated random error variance
   b. Induced artificial bias

4. Statistical tests to evaluate material control:

   a. Operators MUF*
   b. MUF* adjusted for bias

Item identification consists of a 100% inspection effort to locate every item in the plant. included in "items" are the in-process bulk storage vessels that are not cleaned out for inventory. The qualitative and quantitative measurements are based on a random sampling plan which for each facility usually results in a measurement of 50 to 100% of the material in order to meet IAEA detection criteria. The major quantity of material to be verified is normally contained in items received or shipped and in storage vessels.

An indication of the quality of material control and accounting at facilities satisfying IAEA criteria for adequacy can be obtained by comparing material balance accuracy in these facilities with requirements in the U.S. Table 3.1 shows the IAEA expected accuracies of material balances relative to throughput.

TABLE 3.1. IAEA EXPECTED ACCURACY (STANDARD DEVIATION OF A MATERIAL BALANCE EXPRESSED AS PERCENT OF THROUGHPUT OR INVENTORY)

Facility Type	Expected Operators Accuracy
Uranium Isotope Enrichment	±0.2%
Uranium Fuel Fabrication	*0.3%
Plutonium Fuel Fabrication	±0.5%
Uranium in Power Reactors	*0.2%
Reprocessing, Uranium Line	±0.8%
Reprocessing, Plutonium Line"	±1.0%

"Material unaccounted for.

A comparison with the U.S. regulatory requirements on measurement accuracy (see Table 2.1) shows that U.S. standards are somewhat more demanding than those of the IAEA.

The IAEA, under INFCIRC/153, utilizes containment and surveillance measures to establish the material balance areas and define key measurement points used in the accounting verification. These safeguards measures are designed to guard against material being diverted into unmeasured flow or inventory and against tampering with the IAEA measurements or inventory procedure by the facility. This approach has been exercised in joint programs between the IAEA and the Brookhaven National Laboratory which included a three-month exercise by up to 16 inspectors at the Nuclear Fuel Services, West Valley, New York, reprocessing plant during 1969.(10) For the past five years, the IAEA has been developing automated instrumentation for containment and surveillance such as optical surveillance cameras, (11) gamma sensors or thermocouples to detect unauthorized transfers of material, (12) unattended radiation monitors for surveillance of personnel and packages at portals, (13) and nuclear detectors to monitor isotope concentrations and verify operators reports of flow. (13) The application of seals to discrete containers of SNM is now a conventional safeguards measure in routine use by the IAEA. (11) In addition, the Agency is investigating improved sealing devices such as random fibre optical finger-printing seals that are field readable.

3.2 PHYSICAL SECURITY REQUIREMENTS IN LICENSING REVIEW

In a presidential message dated May 1975, (6) it is stated that the U.S. has adopted a policy that no future license will be issued for the export or re-transfer of more than 5 kg of highly enriched uranium or of more than 2 kg of plutonium or

U-233 unless the government of the recipient country "has an established system of physical security measures acceptable to the United States." We are unaware of any detailed standards of acceptability beyond a statement that they should be "comparable to those imposed domestically." In any case, there may be reasons for classifying the details of methods and, indeed, we are unsure of whether absolute standards can be usefully applied.

The following ERDA statement, drawn from Ref. 7 (page 6-35) provides an account of the current position:

> "It is impossible to define in a concise recipe what physical standards are "adequate," due to the vast differences in the nuclear facilities of the various nations. What the U.S. does is review the foreign nation's physical-security standards in comparison to analogous U.S. standards and evaluate the purpose of each foreign regulation, relating it to its American counterpart. The determination of adequacy must consider such factors as the nature of the installation or facility, the differing levels of protection required, the technical sophistication of the nation involved, cost aspects, and manpower considerations. If the security measures, as enforced in the country, meet the goals of the American standards, then the foreign nation's standards are considered "adequate," because they are deemed to be "comparable." Various factors are thus considered in evaluating the viability of the standards of another nation. In some nations, for example, labor costs are minimal. lanpower is so abundant that primary reliance on human protection is both feasible and desirable from a monetary standpoint. Thus such compensating features as large numbers of trained guards or active and well-coordinated response forces are factors considered when making an overall assessment. In contrast, the U.S. , labor costs are extremely high and mixed security systems employing both manpower and high-technology systems incorporating detection devices, etc. , are in much wider use.
>
> "During visits to countries in question, U.S. experts review the nation's standards for physical security, the measures being employed, and the enforcement of the regulations and make suggestions on the upgrading and improvement of existing systems. The specific procedures followed in determining the adequacy of a nation's physical security measures are

1. Review of the nation's established requirements for physical security.
2. Comparison of the nation's physical security with current U.S. measures and guides, and any future modifications thereto, taking into account factors that may be peculiar to a particular nation.
3. When appropriate, a direct request of the recipient government for specific information on matters relevant to the entire area of physical-security.
4. When appropriate, visits to facilities involved with such material by a physical-security review team in order to ascertain that the procedures followed are adequate to the situation in that particular nation.

"In implementing this policy, U.S. physical-security review teams have visited 18 countries during the past year, and visits to some 21 additional nations are planned for 1976. By the end of the year, the U.S. will have made reviews of the physical-security measures of all the major recipients of strategic quantities of U.S. nuclear materials and intends to cover all nations with whom it has Agreements for Cooperation, as well as other nations that might receive trigger-quantities through the U.S.-IAEA Agreement.

"The national-security* policies of the foreign state prevent the U.S. from disclosing such information to the general public. Such unpermitted disclosure would result in an improper breach of confidence and would create at least a stress, if not a rupture, in the nations' relations with the U.S.

"In addition, valid nondiplomatic reasons exist for not divulging information on the status of physical-security in a nation. Public disclosure would have the immediate effect of broadcasting to the world at large, including interested terrorist organizations, the details of the security system of the various nations. This could be extremely useful information on the hands of subnational groups or terrorists bent on taking advantage of such intelligence.

"Thus most foreign states continue to keep their specific physical-security measures classified and/or under proprietary restrictions. The results of the U.S. visits are therefore classified, at the request of the nations involved, and the U.S. cannot divulge results of the reviews.

Furthermore, the laws and regulations of the various recipient nations as well as the factors peculiar to each recipient nation make it difficult to present even general observations.

"However, foreign nations are actively committed to developing and maintaining adequate physical-security systems. All the countries visited by U.S. physical-security review teams were familiar with the IAEA guidelines on physical protection. Some nations actively participated in the development of the IAEA guidelines. All of these nations have generally accepted them as the basis for their own physical-security systems. However, in many cases, the visits by U.S. physical-security review teams apparently constituted a real impetus to prepare formal regulations and upgrade the physical-security systems, seemingly acting as a catalyst to subsequent security improvements.

"The U.S. physical-security review teams have been uniformly impressed with the positive attitudes of the authorities in each nation visited. Other countries recognize the importance of having a system of adequate physical-security measures and have a strong incentive of their own to assure protection of their own materials and facilities."

4. Safeguards Research and Future Safeguards

Both NRC and ERDA have safeguards R&D programs. ERDA has a responsibility to develop safeguards for the new energy systems that it develops and also to insure that the safeguards for its military and research programs will meet future safeguards goals. On the other hand, the Energy Reorganization Act of 1974 assigned NRC the responsibility for "confirmatory research." So far this has been interpreted to mean that ERDA would support the bulk of the 'hardware research," the technology development, and the demonstration and Testing of safeguards systems in actual facilities, while NRC has put emphasis on systems studies, on the development of analytical techniques, and on programs which should help it to: (1) define safeguards requirements for the facilities that it regulates, and (2) assess not only compliance of these licensees but also the effectiveness of its role in protecting and advancing the interests of the U.S. public. Before attempting to describe this R&D program, it might be useful to briefly review the past.

Safeguards, as such, began to attract official attention in 1957, when the UN voted to establish The International **Atomic** Energy Agency. Several R & D studies were funded by the Atomic Energy Commission in 1958 and 59, which were primarily addressed to international control or to certain arms control agreements then under consideration. An outstanding safeguards study, which is all but forgotten, was done by Westinghouse for the AEC for one million dollars in 1959. It outlined a system for us safeguards, explored the then available methods for measurement of nuclear materials, developed some new methods, and looked into techniques for physical protection including tamper-resistant recorders and communications. At that point, the AEC lost interest. It supported work on better chemical measurements of nuclear materials and some productive studies of material accounting for nuclear facilities at Battelle in Hanford, Washington. But it was not until 1967, after the big loss of high enriched uranium at Numec and after the US and USSR had agreed on the nuclear non-proliferation treaty, that the AEC finally set up a consistent program of R & D on safeguards.

Until recently, safeguards has not been a matter of high priority to the public or the Congress or the AEC. In the past several years, there has been a greatly renewed interest in the subject of safeguards, and funds to match. But the public and the Congress should not expect that a sudden renewal of interest and money will quickly make up for years of neglect.

The NRC program, as noted above, emphasizes systems studies and the development of methodology to assess safeguards systems and components. The ERDA research, test, and evaluation program will be summarized next. The most important subject for study, which both NRC and ERDA are emphasizing, is that of how to assess and evaluate

safeguards systems and subsystems, of how to make cost-benefit analyses involving imagined threats, untested systems (no significant incidents so far) and consequences ranging from zero to very serious.

4.1 The ERDA Safeguards R&D Program

The ERDA R&D program is described in ERDA 76/122, referenced on p. 8 . The subject to be pursued and the estimated costs for fiscal years 1977 and 1978-81 are reproduced in Table 4-1. Items I-IV are relevant here (V relates to ERDA inspections, VII is an NRC-ERDA central computer data system, VIII is international safeguards support, IX is the ERDA/NRC analytical laboratory, and VI, missing from the Table, is the ERDA personnel clearance program) . The following is a summary of the program described in the ERDA Master Plan document:

Task I - Characterize Threat:

'The product of this task will be the characterization of the capabilities of adversaries, an assessment of probable threats, and the development of a rational way for dealing with them, recognizing that potential human actions cannot be quantified to the same degree as for design failures (reactor safety or reliability). Furthermore, lacking a history of serious hostile acts involving nuclear materials, one has to extrapolate from other experiences of society."

The task includes studies of adversary activities in other areas which may provide insight into possible nuclear threats; detailed analysis of the possible consequences of successful acts of diversion, theft, or sabotage to threaten **or** to cause dispersion of radioactivity or detonation of a nuclear explosive; assessment of the resources that an adversary group would need to undertake and to complete such adversary actions; and careful analysis of all of the conceivable ways that an adversary might pursue to gain her or his objectives.

This set of studies is intended to define design threats for the system designer and to identify all of the possible "adversary action sequences" which the safeguards systems should block. It is recognized that society and technology undergo changes with time that affect the nature of the threats. Consequently, the products of this task are to be reviewed periodically.

Task II - Conceptual Design, Development and Analysis:

"Conceptual design, the evaluation of cost and effectiveness of safeguards systems, and the development of new procedures for such evaluations is performed to assure that safeguards funds are allocated for maximum benefit and possible trade-off alternatives are examined. This task is divided into: (1) the development of effectiveness evaluation techniques and, (2) the development of generic concept definitions for fuel cycle facilities."

SAFEGUARDS AND SECURITY PROGRAM RESOURCE REQUIREMENTS

FOR FY-1977 AND FY 1978-81

(Outlays in Millions)

Table 4.1

TASK	FY-77 REQUEST	ESTIMATED RESOURCES FOR FY 78-81*
Operating		
I. Characterize Threat	$ 0,2	$ 005
II. Conceptual Design, Development and Analysis	2.8	4.0
111. Technology, Equipment, & Modular System Development & Test and Evaluation	9.7	33.0
IV. Integrated System Design (Plant Specific)/Installation & Test and Evaluation in Operating Environment	6.3	38.9
V. Assessments and Inspections	0.5	7.2
VII. Nuclear Materials Management and Safeguards System (NMMSS)	0.8	903
VIII. International Activities	0.7	3.8
IX. Safeguards Analytical Laboratory	1.3	5.3
Sub-Total	$ 22.3	102. (P**
Capital Equipment	2.5	14.5
Construction	2,5	2.4
Sub-Total	$ 27.3	118.9
VI. Personnel Clearance Program	10.0	40.0***
TOTAL**	$ 37.3	$ 158.9

*FY 1977 dollars - no escalation reflected in these figures.

**It is imPortant to note that these figures do not include safeguards implementation costs, i.e., the cost of implementing safeguards systems at operating facilities. Such costs are borne by the sponsoring ERDA divisions, and are reflected in their budgets.

***These totals represent the FY 1977 Presidential Budget Commitment Projection.

Taken from ERDA-76/122 (p. 32), Safeguards Master Plan

Effectiveness evaluation techniques are necessary in order to assess generic conceptual designs, specific safeguards system designs, and subsystems. Task II lists the following projects and schedules:

1. Effectiveness evaluation models for physical protection of facilities and shipments against overt or covert -threats. Preliminary computer based models have been developed by Brookhaven National Laboratory and the Sandia Laboratories for this purpose. They are being used to assess the effectiveness of physical protection facilities at ERDA facilities and to evaluate safeguards systems being developed by ERDA laboratories. The schedule calls for improvement of these analytical tools as experience is gained (references 1, 2)*.

2. During the last several years, a technique has been developed by a group at the National Bureau of Standards to asses the vulnerability of safeguard systems to adversary actions on the part of facility employees or others permitted access to nuclear facilities. It is known as "Diversion Path Analysis" (reference 3)*. This is a more difficult task for analysis than that described above. The method is being applied to a number of ERDA facilities in order to determine its utility and how it could be improved. The schedule calls for an effective analytical tool, in use, by 1978-80.

   NRC has supported studies of the vulnerability of nuclear power plants to sabotage, at Sandia, and is supporting the development of an effectiveness evaluation, computer-based, model at Sandia for protection of reactors (reference 4)*.

3. The generic safeguards systems designs, described in the Master Plan, are for future privately-owned, nuclear facilities which would process substantial amounts of special nuclear materials, e.g., reprocessing plants, plants to convert plutonium-nitrate to plutonium-oxide, mixed-oxide fuel fabrication facilities, breeder reactors, etc. Although identified as 'generic" designs, the designs are, in fact, quite plant specific and are generated with participation of the commercial plant designers in order to insure that the safeguards features are compatible with operations and to obtain realistic estimates of the costs. Specific facilities which are being **or** will be studied are: the Allied-General Reprocessing Plant at Barnwell, S.C., the Westinghouse mixed-oxide fuel fabrication plant intended to be located at Anderson, N.C., the "high-performance fuel laboratory" being constructed by ERDA contractors at Richland, Washington, to fabricate breeder-reactor fuel, and the Clinch River Breeder Reactor, proposed for Oak Ridge, Tennessee (reference 5)*.

*See next page for references 1-5.

References:

1. "Simulating Physical Protection Against Overt Attacks at Facilities Using, Processing, or Storing Nuclear Materials." W. Marcuse and J. P. Indusi, Journal of the Institute of Nuclear Materials Management, IV, No. III, 1975.

2. "Safeguards System Effectiveness Modeling," H. A. Bennett, et al. (Sandia), J. Inst. Nuc. Mat. Man. V, No. III, 239, 1976.

3. "Diversion Path Analysis Handbook" (2 vols.), by Nat. Bureau of Standards, Center for Radiation Research. Prepared for US-ERDA Div. of Safeguards and Security, October 1976.

4. "Safety and Security of Nuclear Power Reactors to Acts of Sabotage," D. J. McCloskey, Sandia Lab. report SAND-74-0069.

5. References 54, 55 and 56.* Unclassified papers on safeguards for a mixed-oxide fuel fabrication facility should be issued soon. The general concepts are described in: "Design of Integrated Systems for New Fuel Cycle Plants," J. M. de Montmollin and R. B. Walton, J. Inst. Nuc. Mat. Man., V, No. III, 317, 1976.

*See Reference List at end of this Appendix.

Task II also includes R & D on nuclear materials information systems and on inspection strategies.

Task III- Technology, Equipment and Modular Systems, Development, Test and Evaluation:

"The effort is directed toward the development and test and evaluation of. recommended improvements in technology, equipment, and/or modular subsystems for:

- physical protection;
- material control and accountability; and,
- detection and recovery.

These improvements, when tested and evaluated, are then applied in developing safeguards systems designs for specific types of facilities under Task IV (Figure 4.8, page 45). Specific equipment and subsystems being developed, tested, and evaluated are shown in Figure 4.7, page 44. A comprehensive research, development, test and evaluation implementation plan is contained in Appendix I."

This category includes the large number of safeguards projects concerned with hardware items and techniques. Some of these are relatively highly developed, due to past R & D programs, others will require substantially more research and testing. The general nature and scope of these activities is suggested in the following list of items: In support of physical protection: (1) intrusion detectors and entry control, computer security, effectiveness of barriers, guard equipment and training.

In support of material control and accountability: (1) improved measurement methods, on-line measurement technology, automated sampling and analysis, (2) better standards for analytical and non-destructive assay measurements, (3) improved techniques for measurement quality control, (4) development of measurement systems for advanced, large-scale nuclear facilities.

In support of detection and recovery: (1) mobile diagnostic equipment, and (2) high-resolution detection arrays.

Task IV - Integrated System Design, Installation, Test and Evaluation in Operating Environment:

'Concurrent with the development, test and evaluation discussed in Task III, effort is directed toward the concept definition, development, acquisition*, installation*, and evaluation* of integrated safeguards systems for selected generic classes of facilities. In an operating environment, conceptual systems are then modified to adapt to real work economic and operational constraints and then serve as working-model guidelines for the implementation of alternative systems."

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*in coordination with other ERDA program divisions

In addition to the whole-plant designs described above, ERDA is supporting the design, construction, and testing of a number of subsystems which will be components of such systems. These include: (1) development and implementation of automatic, on-line measurements equipment at the plutonium processing facility at Los Alamos. Items have been installed and tested in the existing, old facility. The new facility, to be operational in 1978, will have a complete system which should provide for material control and accounting on an essentially continuous basis so that material balances can be performed after each shift rather than once every two months, as is presently the case. (2) Design and demonstration of rugged physical protection and tight item control of containers of nuclear materials in vaults (Sandia and Los Alamos), and (3) installation and testing of physical protection techniques at the Sandia Laboratories research reactor.

4.2 Integrated Safeguards, a Summary

The integration of the previously separate safeguards functions of physical protection, and material control and accounting has received major attention during the past years (e.g., References 47, 48, 49)*; and a major ERDA program is now directed to the definition of a systems solution to the Safeguard problem. The program envisages a plantwide system having advanced physical protection mechanisms for deterring and defeating outside attack, comprehensive management of personnel entry and access to sensitive areas, explicit controls on plant procedures to provide the basis for techniques for detecting internal discrepancies, and the use of DYMAC-related accounting procedures. A description of the approach is excerpted from an ERDA paper (Ref. 55)* in the following paragraphs:

Current program objectives have been established as follows:

1. Develop, assess, and assure the availability of cost-effective safeguards systems for application of ERDA facilities and the commercial fuel cycles.

2* Assist the International Atomic Energy Agency (IAEA) in its safeguards role in guarding against the proliferation of nuclear explosive devices and defining effective safeguards internal control and physical protection systems, in conduction with efforts of foreign nations, for guarding against domestic threats to nuclear materials and facilities.

3. Develop, assess, and assure implementation of effective safeguards and information control systems for the protection of special nuclear material, classified information and property at ERDA, selected other US Government and privately-owned facilities.

*see Reference List at the end of this Appendix.

"ERDA's Division of Safeguards and Security (DSS), with the assistance of Sandia Laboratories, Los Alamos Scientific Laboratory (LASL), and Brookhaven National Laboratory (BNL) is developing design concepts for an integrated and balanced facility engineered safeguards system (ESS). The concepts are directed at application to LWR and LMFBR fuel cycle facilities and enrichment facilities. These safeguards systems would make use of the work being conducted under R & D programs to develop methodology, equipment, subsystems, and systems for better protection of SNM and facilities containing SNM.

"The objective of the ESS is cost-effective protection against a wide range of threats, both overt and covert, without causing an unreasonable impact of facility cost or operation. The ESS will interact closely with all aspects of plant operation. The system requires the computer to monitor and verify the integrity of the materials control and physical protection elements before operation can be initiated or to allow further processing to continue.

The ESS contains three interacting components, or centers:

.Personnel control system (PCS).
•Item operations control system (IOCS). .
.Material accountability system (MAS).

"The ESS works, conceptually, by plant or production management assigning a production task to the operations people. The specifics of the task - number of people, names of people, quantities of SNM, material access areas, time windows, etc., are included in the management-authorized work "order. The MAS then interacts with the other two centers and monitors production operations on the basis of the work order information. The MAS verifies location and status of the SNM. The PCS would verify the identity of the workers and permit entry into the work area. Closed-loop control insures all steps in the operation are followed in the authorized sequence and by approved personnel. If an off-normal or unauthorized condition takes place, an alarm is initiated or other appropriate response action is taken. The response is not arbitrary but is determined in advance. Integration with the facility - and the safeguards actions of the ESS - are established by plant management after consulting with the facility designer, processing people, the safeguards staff, and others."

Thus, in addition to providing for advanced management of physical protection and materials control, the system provides an automated management function which may have a major impact on the pervasive problem of detecting and determining thefts by insiders. For example, one main concern is to define in broad terms how the automatic system of safeguards shall handle prevention of theft during non-routine events such as fire, criticality incident, evacuation of injured employee, equipment breakdown, maintenance, etc. Another is the definition of means by which the broad class of administrative thefts by those in responsible positions in a

plant can be protected against without substantial interference with plant procedures and without oppressive surveillance.

4.3 IMPROVED MATERIAL BALANCE ACCOUNTING FOR MONITORING COVERT DIVERSION

Improvements in material balance accounting for detecting covert diversion can be achieved in two ways: improving measurement system accuracy and reducing the amount of material in the balance by more frequent inventories. In the following discussion of these improvements the material balance is formed by periodically measuring SNM after it has been removed from the process. Section 4.4 discusses concepts for real-time material control in which the SNM is measured while it is in the process.

improved Measurement System Accuracy

Measurement system accuracy can be improved by more accurate measurements and by reducing the amount of material that is difficult to measure. These difficult-to-measure materials are scrap, waste, and residue remaining in equipment after most material has been removed from the process for inventory. In the late 1960's and early 1970's heavy emphasis was placed on the development of nondestructive assay (NDA) for scrap and waste measurement because in many existing facilities no accurate measurement techniques existed. ERDA support for development of improved NDA has continued at Los Alamos Laboratory (LASL), Lawrence Livermore Laboratory (LLL) and Mound Laboratory[15]* on scrap and waste assay and on the optimization of NDA's potential for prompt, on-line measurement in a real time accounting system. The result has been a significant improvement in ability to measure scrap and waste.[16, 17] This improvement combined with improved process design for higher yields means that scrap and waste measurements are not expected to contribute significantly to material balance uncertainty in future large commercial nuclear facilities.[18] The dominant uncertainties in material balance accounting in these facilities

See Reference List at the end of this Appendix

will be the measurement of feed and product by laboratory analytical measurements and, for more frequent material balances, the measurement of equipment residue. This is the case even though laboratory analytical measurements* are the most precise and accurate techniques available.

ERDA is supporting the development of improved and automated analytical measurements at New Brunswick Laboratory (NBL), LLL, and LASL.[15] However, a recent survey[16] of measurement accuracy shows a significant difference in the accuracies achievable in production facilities compared to those achieved in research and development laboratories. Improvement of production accuracy to best R&D laboratory accuracy would reduce material balance uncertainty by approximately a factor of three to five, i.e., from 0.5% to 0.2% or 0.1% of flow for non-reprocessing plants and from 1% to 0.3% or 0.2% for reprocessing plants. To put these accuracies in perspective, the standard reference materials provided by the National Bureau of Standards and against which all measurements are ultimately calibrated have an uncertainty of approximately ±0.06%.[20] Thus, to achieve these improvements in production facilities would mean elimination of nearly all other sources of measurement error, such as errors arising from non-homogeneity of the sampled material, vessel volume uncertainties and actual sampling errors.

Improved analytical measurements would not be useful in reducing the uncertainty in frequent material balances unless a Parallel gain were made in measuring equipment residue. NRC has supported work at Argonne National Laboratory that resulted in guidance on equipment design to minimize this problem.[21,22]

*These laboratory techniques such as gravimetry, electrochemistry, and mass spectrometry have one standard deviation accuracies from 0.05% to .5% whereas NDA of scrap and waste is only accurate to 1% to 5% and 5% to 15%, respectively. However, feed and product account for greater than 90% of the material in the balance whereas scrap and waste account for only 1% to 5% and 0.25% to 1%, respectively.

However, in large plutonium facilities approximately five kilograms of the material in a material balance may be residue remaining after clean-out for inventory. Recent NDA measurements of plutonium equipment residue [23, 24] made in accordance with NRC guides [25] have demonstrated uncertainties from 10% up to 50%. The best accuracy might reduce the residue contribution to the material balance uncertainty to approximately 0.5 kilograms for large facilities.

Increased Material Balance Frequency

The absolute uncertainty in a measured material balance is proportional to the amount of material measured and this, in turn, is proportional to the time interval between material balances. Thus, the more frequent the material balance, the lower the absolute uncertainty in each inventory period. In addition, reducing the time between material balances improves the timeliness of accounting and, in the limit of real-time accounting, means that information would be avail to detect diversion in time to permit more prompt remedial action. Calculations of frequent material balance uncertainties for future large commercial plutonium facilities were performed as part of the NRC Special Safeguards Studies. [26] The theoretical calculations indicated that considerable reduction in material balance uncertainty could be achieved for both fuel fabrication plants and reprocessing plants through taking frequent inventories. However, these material balances are based on inventories requiring the shut-down and clean-out of the process and therefore result in considerable lost production. In the fabrication plant, inventories conducted in a dynamic sequential manner [27] around batches of material would fit naturally in with normal operation. In the reprocessing plant approximately two weeks would be lost per inventory plus

one or two weeks during which the process would not operate at peak efficiency due to shut-down and start-up. Dynamic inventory techniques for reprocessing plants based on introduction of a tracer isotope to separate the continuous stream into batches of material have been studied theoretically at Argonne National Laboratory. (28) This technique would not require shut-down of the process and could be used for material balances around batches of material that would naturally exist in a reprocessing facility. However, there has been no demonstration of such dynamic inventories of liquid processes.

Conclusions on improving the Accuracy Of Accounting

Improvements in material balance accounting can be achieved by improving the accuracy of laboratory analytical techniques and NDA of equipment residue (assuming waste and scrap generation are minimized). Further improvement will result from increased material balance frequency. However, frequent material balances could have an unacceptably severe impact on plant operation and plant economics. Computer based accounting systems that could process data in real-time for these frequent material balances have been studied. (29)

The necessary improvements in measurement accuracy and material balance frequency can only be determined once an absolute threshold for diversion detection has been established. NRC postulates that an accounting system having a LEMUF of 2 kg plutonium could give assurance that material for even a single weapon had not been diverted. The Appendix suggests that the risk of removing more than a kilogram at this LEMUF is significant. improved nuclear materials accounting systems could be configured to detect approximately two kilogram thefts of plutonium for large mixed oxide fuel fabrication plants. Equally effective accounting in large reprocessing

plants such as the still unlicensed AGNS plant at Barnwell, S.C. appear infeasible, unless real-time material control can be achieved.

Material accountancy thus cannot be relied upon, now or in the future, as the sole safeguards measure, either in national or international safeguards. For IAEA safeguards, containment and surveillance must come to play more than a supplementary role (see Volume I, Chapter VIII, especially pages 206-207 and 209-211); for U.S. domestic safeguards, physical security and material control must continue to play vital roles.

4.4 REAL-TIME MATERIAL CONTROL

RETIMAC

In the preceding section on improved material balance accounting, material balances which might be performed monthly, biweekly or even weekly were discussed. These might be performed using on-line computers to acquire, process and store much of the measured data on material quantities. Real-time material control would include performing material balances even more rapidly (daily, end of shift, or nearly instantaneously), and it would involve even more extensive use of on-line computers. In addition, real-time material control offers the possibility of generating a variety of diversion indicators which are derived, not from material balances, but rather from data on the material processes.

To obtain material balances more rapidly, it is necessary to maintain running accounts of material transfers and to perform rapid inventories of materials in process* and in storage. These materials include the mainstream feed and product materials as well as the sidestreams of clean scrap, dirty scrap, solid waste, liquid waste and analytical sample materials. The accuracy of more timely determinations of material transfers and inventories varies considerably depending on the method and on the material. There are two general methods for obtaining such determinations: direct on-line assay measurements and the use of indirect on-line measurements together with process models to estimate material quantities.

The most general concept of real-time material control has evolved in a series of four papers (30) by T. E. Shea of NRC. Shea's concept, which in his first three papers is called RETIMAC (REal-TIme MAterial Control) has evolved to consist of the following four elements:

*Here in-process materials refer to all materials not in storage, and include residual holdup or heels, and materials in transit to, from and between processes.

- Material Isolation - use of barriers to limit operator contact with material to only non-routine operations which would be performed under intensified surveillance.

- Inventory Control - use of process control for unit processes to detect anomolous operations which may indicate diversions; use of storage control for vaults and buffer storages to restrict access to stored materials; and use of internal transfer control to protect materials being transferred between unit processes as well as into and out of storage.

- Inventory Characterization - use of on-line instrumentation to assay material flow streams into and out of unit processes; use of on-line instrumentation to monitor process parameters together with appropriate process models to estimate in-process inventories; and use of on-line instrumentation to perform in situ assay of residual holdup in process equipment after runout or cleanout.

- Inventory Containment Analysis - use of an appropriate hierarchy of computers and detailed models to perform real-time analysis of all data acquired to detect diversions as promptly and as credibly as possible.

As part of the NRC's Special Safeguards Study, Lawrence Livermore Laboratory[31] and Science Applications, Inc.[32] examined how the RETIMAC concept might be implemented in a future high-throughput mixed-oxide fuel fabrication plant like the one planned by Westinghouse for construction near Anderson, South Carolina. Based on these two studies, researchers concluded[30] that "timely, localized detection systems can be designed to substantially improve the detection sensitivity for covert theft over the systems currently required in U.S. licensed

processing facilities. Further, this capability can be cost-effective and provide many corollary benefits to other plant operational systems."

Science Applications, Inc. later performed a similar, but less extensive, study for a high-throughput spent-fuel reprocessing plant similar to the one being built by Allied-General Nuclear Services near Barnwell, South Carolina. The results [33,34] of this study showed that the diversion detection sensitivity associated with rapid material accounting is less for the reprocessing plant than for the fabrication plant.

One of the key components of real-time material control as envisioned for RETIMAC is the use of process models together with certain limited measurements to estimate quantities of interest, such as in-process inventories. Related modeling work has been reported in a number of recent papers [35,36,37,38,39,40,41,42]. Further development of the concepts is presently underway at Lawrence Livermore Laboratory.

Another real-time material control concept, called DYMAC (for DYnamic MAterials Control), is being developed and implemented at Los Alamos Scientific Laboratory [43] (LASL). DYMAC is a system of in-plant nondestructive assay (NDA) instrumentation coupled with automated data processing equipment to provide essentially real-time accounting and material control on a unit process basis. DYMAC consists of four subsystems.

- NDA Instrumentation - on-line NDA instrumentation to assay a variety of materials, with design emphasis on automation to minimize operator action, built-in calibration capability, improved precision and accuracy, operational compatibility, reliability and maintainability.

- Data Acquisition - NDA instrumentation coupled directly or through minicomputers or microprocessors to a central computer; operator inputs to the central computer using a variety of terminals ranging from a few control buttons to a fully interactive video display with hard copy capability.

- Data Base Management - central computer hardware and software to organize incoming data into a file structure for retrieval in an efficient manner.

- Real-Tine Accountability - using the data base, performs unit process accounting for all material in plant by calculating current inventories for each area, MUF and LEMUF by unit process area and by material batch, and control limits; monitors for deviations outside control limits and for incomplete internal material transfers; maintains the standards and measurement control program; and generates printed reports.

DYMAC is being implemented at LASL in three phases. In phase 1, the present LASL plutonium facility at the DP site is being used as a test bed for component development and operator training. This work includes evaluation of on-line NDA instrument performance, upgrading of off-line NDA instruments and operation of a prototype four-terminal account-ability system for one unit process accounting area. Phase 11 is the design and installation of a DYMAC system for the new plutonium processing facility (TA-55) which is presently under construction at LASL. This system, designated DYMAC/TA-55, tentatively consists of 15 unit process accounting areas with 20 to 30 terminals, 25 weighing devices and 20 to 30 NDA instruments. Installation of DYMAC/TA-55 is scheduled for June 1978. Phase 111 is a program to evaluate the performance of

DYMAC/TA- 55. Operation of DYMAC/TA-55 in the new LASL plutonium processing facility is intended to demonstrate:

- reliability and operational feasibility of on-line NDA instrumentation in a production environment,
- accurate and efficient data collection,
- common data base management,
- timely sensitivity to missing nuclear material, and
- capability for production control, quality assurance, and financial management.

In addition to the above work, the concept of real-time material control has been examined [44] in some detail by J. E. Lovett of IAEA. More recently, Lovett has discussed [45] the international safeguards aspects of real-time material control.

In summary, considerable development work and in-plant demonstration is required before the effectiveness and costs of real-time material control can be fully assessed.

4.5 HARDENED FACILITIES

Hardening the physical protection system of nuclear facilities against outsider attacks can be accomplished by making three general types of improvements.

- Use of more and/or better protective mechanisms,
- Better integration of the protective mechanisms,
- Upgrading quality assurance for the protective mechanisms and the integrated system.

The protective mechanisms referred to are the security force, security procedures, and security hardware and software. In addition, certain aspects of facility design such as the physical layout, the construction of walls, doors and roofs, the extent to which the facility is underground, and some facility procedures like emergency plans can have direct impact on the overall effectiveness of the physical protection system against outsider attack. The design and evaluation of such systems is addressed in a later section. Here, some of the recent developments in improved protective mechanisms for physical protection are summarized. Much of the information presented here is from four recent review papers by O.E. Jones [50,51] of Sandia Laboratories, H.J.C. Kouts [52] of NRC*, and J.J. Bastin and E.A. Conrads [53] of Westinghouse.

Development of advanced security devices and systems is sponsored by a number of federal agencies such as ERDA, Air Force, Army, Navy, Defense Nuclear Agency and Federal Aviation Administration. Probably the largest program with direct applicability

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* Now at Brookhaven National Laboratory.

to nuclear safeguards is at Sandia Laboratories under the primary sponsorship of ERDA. Some of this work was documented[54, 55, 56] recently for NRC's Special Safeguards Study.

Many of the protective mechanisms which have been under study are listed below by functional category.

- Portal Control (verification of personnel identity): devices based on unique human characteristics, including fingerprints, handwriting and voice prints–photograph retrieval from facility storage for comparison with appearance.

- Portal Control (search for SNM and explosives): detectors for SNM--search-dogs or other animals, and devices which examine individual absorption lines in the ultraviolet region for explosives search.

- Intrusion Alarms: CCTV with automatic motion detection alarm -- buried line sensors (magnetic, seismic, and pressure) -- free-standing sensors (infrared, microwave and radar) -- fence-mounted sensors (vibration and tilt) -- sensors in coincidence to reduce false alarm rate -- reduced vulnerability to tampering.

- Surveillance and Assessment: CCTV with alarm-actuated video tape recorder -- low-light level CCTV -- moving-target radar.

- Passive Barriers: explosion resistant doors -- vehicle barriers -- alarm-actuated closing and locking of doors.

- Active Barriers: dispersal of foam,smoke, tear gas or other such agents to delay attackers.

- Guards: motivation -- training -- deployment plans.

- Communication and Control Center: protected and supervised data lines -- message authentication -- hardened area -- computerized preprogrammed response to alarms, with manual override.

In addition to the above items, several systems, such as an advanced item control system for a SNM storage vault [51] and an integrated portal control system, [57] have been developed. Also recent studies were performed which focused on special topics, such as security forces [58] and psychological deterrents. [59]

4.6 TRANSPORTATION SAFEGUARDS

Most of the SSNM transported today (excluding shipments of nuclear weapons) involves government-owned materials moving between contractor/licensee plants. The majority of these shipments had been carried out by commercial transportation companies* operating under Interstate Commerce Commission authority and in accordance with the transportation requirements specified in 10CFR73[60]. The present traffic level is of the order of hundreds of shipments per year. As the nuclear industry matures, this picture may change in the following ways:

- An order of magnitude increase in the traffic level could occur by the year 2000.[61]
- A significant fraction of the future traffic level could involve commercially owned SSNM for nuclear power applications.

In preparation for this possible expansion in transportation activity involving commercially owned SSNM, the Nuclear Regulatory Commission has supported efforts to assess the effectiveness of existing and future transportation safeguards. In addition, ERDA has an active development program underway at Sandia and other laboratories to develop new safeguards technologies for transportation links. NRC and ERDA are coordinating their research in this area; they are also monitoring efforts by agencies within the Department of Defense that are working on related problems.[62]

Efforts to improve the effectiveness of transportation safeguards include the following:[61,62,63]

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*A federally owned and operated transportation system for government-owned materials is scheduled to go into full operation by late 1976.

1. Immobilization system to bring cargo vehicles to a controlled stop and prevent further vehicle movement.

2. Cargo access denial measures to impede penetration of the vehicle and the possible use of devices which would affect an intruder's senses.

3. Driver protection during attack.

4. Effective communications between vehicle and control center during shipment.

5. Use denial techniques to despoil SNM and convert it to a form which requires additional processing for use as an explosive.

6. Develop evaluation methods to determine the nature and extent of the resources and tactics required to successfully defend against an attack on a shipment.

Research on transportation safeguards has already produced results, some of which are described in the technical literature. Much of it concerns hardened cargo vehicle design and improved communications. Portions of the work are classified. Some of the new technology will be introduced into the ERDA Safe-Secure Transportation System for tests under actual operating conditions. (51,64)

An obvious means of reducing the risk of diversion of SSNM during shipment is to minimize or eliminate transportation of SSNM by collocation plants. This concept has been studied by NRC. The results are published in the "Nuclear Energy Center Site Survey--1975 ."(65)

NRC's conclusions relating to transportation are summarized in the following statement:

> "Collocation, by eliminating some transportation links or shortening others, can thus have beneficial effects on safeguards. This is not to say, however, that collocation is necessary in order to achieve an adequate level of security. The analysis performed in the Special Safeguards Study shows that transportation of SSNM can be made secure with bearable costs." (65)

The following is taken directly from Reference 65:

1. "Collocation's principal consequence for safeguards is that it minimizes transportation. The question of whether collocation is desirable from the safeguards point of view initially becomes one of comparing the effectiveness and costs of fixed-site and in-transit safeguards."

2. "Fixed sites **have** the advantage of being able to utilize a sequence of barriers and detection systems. Also, a fixed site typically can depend on a local response force of known size and capability. A major disadvantage of fixed sites is that some personnel must be authorized to have access to both SSNM and vital areas. This compounds the security problem with respect to both the disaffected insider and the outside attacker (who may have inside cooperation) . The need to provide emergency exits to insure the safety of personnel again complicates security and adds to.. the cost of providing barrier integrity adequate against an outside attack."

3. "The primary advantage of an in-transit security system is that the adversary may not know where the shipment will be at any given time, Also, an in-transit system does not suffer from any requirement for personnel access to SSNM. The in-transit security system has the disadvantages that there are fewer opportunities for using multiple barriers or adversary detection systems and that the availability and characteristics of an immediate response force are less well defined. It should be noted, however, that technologies are being developed which will allow transporter systems to impose reasonable delay times on adversary force by applying sophisticated barrier and delay techniques to either or both the transporter and the SSNM container. The in-transit system has somewhat greater exposure to sabotage attempts."

4. "The element of a security system which offers the greatest degree of flexibility is the guard, or, in an in-transit "system, the escort force. The size and structure of this force can be altered to meet the needs of the security systems. The in-transit

security force can be structured to react to a threat in either of two ways: by calling for assistance and delaying the adversary forces until assistance arrives, or by attempting by itself to defeat the adversary. In the first case, the amount of delay required from the escorts must be equal to' or greater than the time required for a response force to arrive. If there is no planned response force, as in the latter case, then the escort force must be strengthened so it can win an engagement with the adversary group."

5. "It is concluded that collocation might have a beneficial effect on safeguards effectiveness; however, transportation safeguards considerations do not preclude dispersed siting."

6. "The cost of safeguards in SSNM transportation would be decreased by collocations."

"A model for the year 1990 which compares collocated and dispersed facilities having total capacities corresponding to 342 MWe and 80% plutonium recycle projects a total (country-wide) annual cost saving from collocation of $1.7 million (in 1975 dollars). (Cf. total annual fuel cycle facility operating costs of $440 million.)"

7. "With respect to safeguards for the fixed facilities, no significant cost differences between dispersed and collocated models are estimated to exist."

The basis of the NRC's conclusions is not regarded as persuasive by many observers. These observers hold that a systematic study of the costs and benefits of collocating fuel cycle facilities has not yet been done.

4.7 REDUCING THE "ATTRACTIVENESS" OF NUCLEAR MATERIAL IN THE FUEL CYCLE

Since the beginning of the nuclear age, one of the more alluring ideas to safeguard nuclear material has been to denature it. Conceptually, the ideal denaturing agent renders the fissile material useless for nuclear weapons without significantly impairing its performance as a reactor fuel. This is practically achievable with uranium by keeping the U-235 (or U-233) concentration sufficiently low in mixtures with U-238. Weapons grade uranium can then only be attained by isotopic enrichment -- a non-trivial undertaking.

An analogous situation does not exist for the other possible weapon material constituent, plutonium-239. There are minor fraction concentrations of other isotopes of plutonium (Pu-240, Pu-242) naturally occuring in reactor produced plutonium. These isotopes do not however, prevent the use of the plutonium as a nuclear explosive. (See Volume 1, Chapter VI.)

plutonium (as well as highly enriched uranium) can, however, be made less attractive radioactively and/or chemically (66 ,67, 68) . The two generic possibilities are often termed:

1. Spiking - the plutonium bearing material is made more radioactive, possibly requiring remote handling and massive shielding.*
2. Blending - the plutonium concentration is lowered by mixing with uranium.

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*^{233}U typically has a natural spike with the inclusion o parts per million quantities of the highly radioactive ^{232}U and daughter products.

Either one of these possibilities are primarily deterrants against a subnational threat. A national entity could easily provide the necessary remote handling, shielding, and chemical separation that might be required.

There are a number of possible methods of making plutonium bearing material radioactively lethal or at least very dangerous. Four spiking techniques are listed in Table 4.3 along with a listing of some specific advantages and disadvantages for each.

Spiking has some additional general assets along with at least three major liabilities. The general assets (which may be negated by countermeasures) include:

- Facilitates detection of Pu in plant (by portal monitors, etc.)
- Assists in recovery operations if Pu is stolen

The liabilities are:

1. The additional costs and potential accident hazards for the required normal handling of spiked nuclear material.
2. The legal aspects associated with adding a potentially lethal substance to protect property.
3. The violation of the "as low as practical" radiation safety philosophy.
4. The increased risk associated with possible sabotage particularly for very high spiking levels.

Although definitive studies have not been performed to accurately pinpoint how much all the additional costs would be for each of the spiking techniques listed in Table 4.3 it is clear that in some cases they may be extensive, particularly if remote maintenance is required. Reference 68 concluded

TABLE 4.3

SPIKING OPTIONS

TECHNIQUE	ADVANTAGES	DISADVANTAGES
1. Partial Decontamination from Fission Products in the Reprocessing Plant.	Utilizes readily available radioactive sources. Intimate mix with Pu.	No fission product with sufficient radiation intensity for long enough period (2 years or more half life). The complexity of reprocessing increases. Possible impact on mixed-oxide fuel performance. Conflicts with "As Low As Practicable" (ALAP) radiation philosophy. Increased costs.
2. Intimate mix of high intensity radioactive source with Pu product.	Current reprocessing flow sheets unchanged. Source strength easily controlled. Intimate mix with Pu.	Costly. ALAP conflict.
3. Tamper-resistant self-contained gamma-ray source placed in product.	Reprocessing steps not affected. Lower cost than other techniques. Sources reuseable.	Protection reduced because activity not intimately mixed with product. Difficult to protect in process material.
4. Irradiate Pu product.	Intimate mix with Pu. Reprocessing steps not affected.	Costly. May not have sufficient radiation source available. ALAP conflict.

that a major cost increase (fabricating spiked fuel) might amount to as much as approximately 2% of the power cost for LWRs and nearly 4% of power costs for HTGRs. The AIF study ([66]) concluded that the spiking liabilities outweighed the possible safeguards gains.

Spiking does not appear to be cost-effective compared to massive containment and stringent physical security.

Blending alternatives to reduce material attractiveness have received more industrial support than the spiking option ([66, 69]). Basically, the blending of uranium with plutonium accomplishes what eventually occurs within every fuel fabrication plant. The technique for blending, i.e. , wet blending, dry blending, and the degree of blending, are all possible variables. The net safeguard result is that a larger total quantity of material would have to be diverted to obtain a strategic quantity of plutonium. To utilize the strategic quantity of plutonium in a nuclear explosive would require a chemical separation of the plutonium from the uranium. This may be a substantial barrier for a subnational group. For a national entity with available resources, blended material might cause some delay in the construction of a weapon, but would not constitute a serious barrier.

Various degrees of blending, all accomplished at a reprocessing plant, have received consideration.

1. Dilute Blend

All light water reactor recycle fuel would contain from 0.2 to 0.6% plutonium: This could be accomplished by never separating the plutonium and uranium in the reprocessed spent fuel. An inherent advantage of this proposal is the most effective utilization of the plutonium. On the other hand, significant cost and safety liabilities accrue at the fuel fabrication plant, particularly if the plant were originally built to handle only uranium.

2. Custom Blend

In this case the blend contains from 2 to 5% plutonium that could in principle be directly utilized by the recycle fuel fabrication in the manufacture of the recycle fuel. A problem here is that the blended material would have to meet the individual fuel manufacturers specifications and quality assurance tests. This is not a practical option if custom blends have to be prepared for a number of recycle fuel manufacturers.

3. Master Blend

Here the blend might vary from 30% down to possibly as low as 7%[69] plutonium. The master blend would then be shipped to the fuel fabricator and further diluted and processed as the fabricator requires to suit his manufacturing process. A 20% to 30% master blend concept has received the endorsement of the AIF study group ([66]) as providing "the best balance between risk reduction and economics in these steps in the fuel cycle."

4.8 REDUCING THE RISK OF NATIONAL DIVERSION--MULTINATIONAL FUEL CENTERS

The concept of regional fuel cycle centers (RFCC) has been developed and advocated in the context of several world issues: how to provide the institutional structure for smaller nations to obtain the presumed benefits of fuel recycling, how to assure the security of sensitive nuclear material, and how to efficiently dispose of nuclear waste. The most recent and thorough review of the RFCC concept is being made by the IAEA. (70) Other literature dedicated to this subject has typically been directed to a policy level rather than enumerating the practical aspects of initiating a program. It is felt that the final IAEA report*will serve as the backbone of operational RFCC's, should they be implemented, largely because it relies on experience gained in previous international ventures such as EUROCHEMIC, URENCO and EURODIF for practical understanding,

The study says the RFCC concept envisages countries joining together for the purpose of constructing and operating facilities which are required for the following activities:

- Transport of spent fuel from reactor sites to the RFCC
- Storage of spent fuel
- Reprocessing of spent fuel
- Storage of resulting waste products and re-usable fissionable material
- Treatment of waste
- Conversion and fabrication of fissionable materials into new fuel elements
- Transport of new elements to reactor operators
- Long-term waste management.

The RFCC concept is not dependent on regional groupings in a narrow geographical sense. If the fuel enters or leaves the

*(Ref.: Regional Nuclear Fuel Cycle Centers, Vol. 1, Summary 1977 Report of the IAEA Study Project, International Atomic Energy Agency, Vienna, 1977, STI/PUB/445)

RFCC in a secure form, transport distance per se should not dictate service only to contiguous or nearby countries, Nor is the concept necessarily dependent on establishment of entirely new facilities; centers like Windscale (U.K.), La Hague (France) and Barnwell NFP (U.S.A.) could serve as the core of RFCC's. The processes listed above may be provided at an RFCC as demand arises.

The RFCC concept is one of concentrating facilities and does not imply the introduction of new processes. Typical basic criteria of an RFCC are shown in Table 4.4 and illustrated in Figure 4.1. The criteria are essentially comparable, from the standpoint of safeguards and security of the physical processes involved, to any other fuel cycle center. Therefore, implementation of RFCC's depends primarily on international acceptance of the need for reprocessing, international cooperation given a decision to reprocess, and the economies (and disadvantages) of scale.

The RFCC Study has identified these main topics for international discussions:

1. Legal status and structures
2. Governmental/non-governmental roles
3. Internal administrative structure
4. Commercial/service roles
5. Industrial arrangements
6. Technology (use, control, etc.)
7. Financial (basic policy considerations)
8. Privileges and guarantees
9. Membership, duration, etc.
10. International agreements

Assuming that institutional agreements can be successfully arrived at, there is good reason to expect RFCC's will reduce the risk of national misuse of fuel cycle centers. Clearly, the RFCC must work well enough for all concerned parties so that no recourse to national facilities is deemed necessary. Several other points for U.S. consideration are raised in this connection:

Table 4.4. Regional Nuclear Fuel Cycle Center Basic Criteria--Phase 1 Study

CONSIDERATION		SIMPLIFYING ASSUMPTIONS
1.	Time Period	1985 to 2000
2.	Capacity of Reprocessing Plants	750 to 3000 Tonnes/yr
3.	Forecast of reactor capacity based on mixed oxide fuel	200 MWe to 1200 MWe
	Size of reactors	200 MWe to 1200 MWe
	No. of reactors	Determined by reprocessing plant capacity, and reactor size
4.	Types of Reactors	LWR--80 to 100% of total installed capacity HWR--0 to 20% of total installed capacity
5.	Fuel cycle Characteristics	Pu recycle to be considered. Also deferred fuel reprocessing.
6.	No. of Reprocessing Plants	1 to 3 per region initially
7.	Fuel Fabrication:	
	UO_2 fuel	outside of center as well as at the center
	- Mixed Oxide Fuel	only at center
	Manufacturing capacity	Determined by the installed electrical generating capacity.
8.	Fuel requirements:	
	- Uranium	Annual requirement Integrated total requirement
	- Enrichment plant	Capacity based on: Pu recycle Deferred reprocessing

Table 4.4. Regional Nuclear Fuel Cycle Center
Basic Criteria--Phase 1 Study (Contd.)

CONSIDERATION	SIMPLIFYING ASSUMPTIONS
9. Spent Fuel Storage	
- At reactor site	1 to 10 years
- At the center	1 to 10 years Adequate to satisfy optimal fuel reprocessing plant capacity. Alternately, when breeder requirement for Pu demands reprocessing of spent fuel, say 1995 (i. e. , 10 years storage)
10. Pu Storage	Up to 1995 if no Pu recycle occurs. Thereafter additional Pu storage capacity not necessary because of its use in breeders.
11. Radioactive waste management	
- From reprocessing plant	Waste solidification at center
- From fuel refabrication plant	Waste solidification at center
- From power reactors	Processing at reactor site, hence not to be considered.
12. Waste storage or disposal	Retrievable storage at center or elsewhere after solidification for long term For short term up to 10 years, most economical method Ultimate disposal at center or at remote location
13. Transport	
- For spent fuel	In casks according to regulations recommended by IAEA. By road, rail and sea.
- For radioactive waste and H.L.	According to regulations recommended by IAEA By road, rail and sea.
14. Discount rate	10%

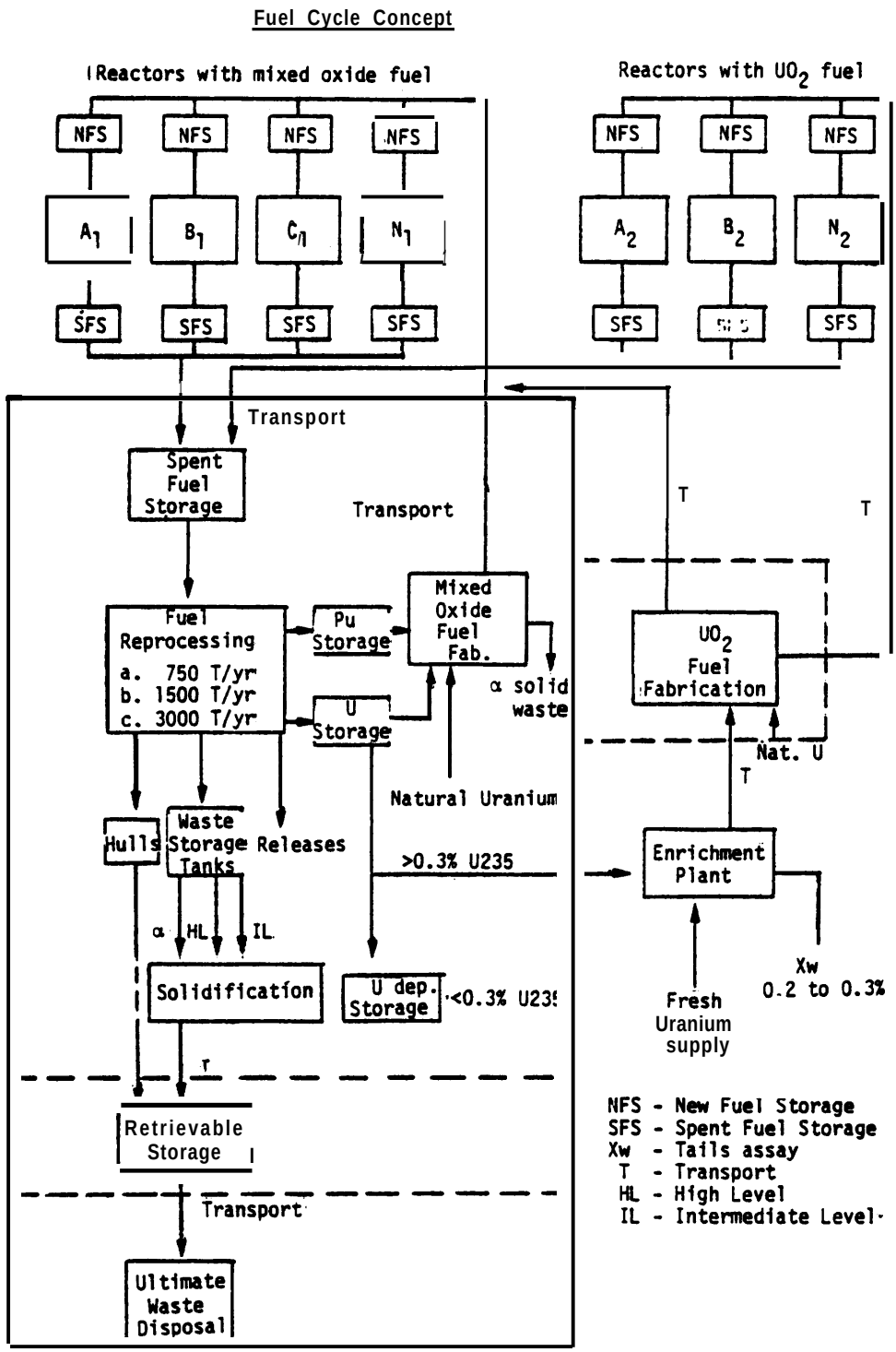
Fuel Cycle Concept
Reactors with mixed oxide fuel
Reactors with UO_2 fuel
NFS
SFS
A_1
B_1
C_1
N_1
A_2
B_2
N_2
Transport
Spent Fuel Storage
Transport
Fuel Reprocessing
a. 750 T/yr
b. 1500 T/yr
c. 3000 T/yr
Pu Storage
U Storage
Mixed Oxide Fuel Fab.
α solid waste
UO_2 Fuel Fabrication
Nat. U
T
Natural Uranium
Hulls
Waste Storage Tanks
Releases
>0.3% U235
Enrichment Plant
α
HL
IL
Solidification
U dep. Storage
<0.3% U235
Xw
0.2 to 0.3%
Fresh Uranium supply
Retrievable Storage
Transport
Ultimate Waste Disposal
NFS - New Fuel Storage
SFS - Spent Fuel Storage
Xw - Tails assay
T - Transport
HL - High Level
IL - Intermediate Level

Figure 4.1

- Sponsors should proceed on the premise that the nature of the RFCC operations will require a substantial degree of governmental involvement. Definite matters of government discretion are (a) the nature of services available to non-partners, (b) the extent to which partners shall fund an RFCC and (c) the disposal of radioactive waste.

- Who shall construct and maintain the plant(s)? Are standardized components an issue?

- Suppliers and/or partners may wish to have technical information remain proprietary or classified.

Thus, the potential benefits of the RFCC concept are that it is a rational use of scarce (and sometimes insufficient) technological and financial resources, that collocation and multi-party interest in the plant could provide a new dimension of safeguards and physical protection of materials wit-h the interest of all partner States in mind, and that the RFCC provides an avenue for effective and safe management of radioactive waste.

There remains much work to be done before these benefits can be weighed against the counterbalancing concerns. A partial list of the latter would include the procedures for management and control among a group of users with common but not identical interests, the acceptability of the waste and effluent liabilities by potential host countries, and (implicit in the whole concept), the need to formulate the institutions in such a way that it would be apparent to the partners that future fuel supplies are assured.

4.9 THE COSTS OF SAFEGUARDS

The costs of safeguards have been estimated by several organizations during the past two years (Refs. (71, 72, 51). The primary breakdown is in: (a) the incremental capital costs of industrial facilities above those for the case where plants are built to normal unsafeguarded standards, and (b) the additional operating costs (e.g., guards) associated with safeguards implementation.

As a general thesis, since the cost of the primary fuel is only a small fraction of the cost of delivered electricity and since safeguards should not increase fuel costs by more than a fraction, we should expect that safeguards will increase the overall cost of electricity by only a small margin. The three studies referenced above all indicate that given a mature nuclear industry, the fractional increase in the cost of delivered electricity due to safeguards is of the order of 1%. However, the absolute annual cost of safeguards is estimated in the range of hundreds of millions to more than a billion dollars. Furthermore, there is a considerable spread in the estimates of the cost of safeguards given by the three referenced sources. As an example of physical protection costs alone, we reproduce results from Ref. 51 in Table 4.5.

These results were developed by Sandia Laboratories for NRC: a mathematical interpolation (based on assuming the industry works at 60% load factor] leads to the conclusion that in 1990 a little over $1 billion out of a $70 billion electrical utility income could be spent on safeguards.

The report of Ref. 71 by E.R. Johnson Associates develops a somewhat lower figure for costs. Given a 500 GWe nuclear power component (at that time projected for the early 1990's, according to Table 4.5.1)* they estimate an annual safeguards

*present projections are lower. See Volume I, Chapter X.

Table 4.5. Projected Costs* of Physical Protection Safeguards for U.S. Nuclear Fuel Cycle Utilizing 80% Pu Recycle

(in 1975 Dollars)

Year	Total Electric Power, GW_e †	Percent Nuclear †	Total Protection Personnel ‡	Safeguards Costs, Mil/KWH Facilities	Safeguards Costs, Mil/KWH Transportation §	Percent of Base Cost Facilities	Percent of Base Cost Transportation §
1980	655	13	7,200	0.49	—	3.8	—
1985	800	29	10,800	0.27	0.005	2.1	0.04
1990	1040	39	15,200	0.21	0.004	1.6	0.03
2000	1575	54	25,800	0.17	0.002	1.3	0.02

*Includes all amortized capital, personnel, and Maintenance costs, and assumes a base electricity cost of 13 mils/kwh.

†Based on Case A projections of Nuclear Power for Growth 1974-2000. WASH-1139(74), USERDA, Office of Planning and Analysis, February 1974. Present projections are considerably lower. See Volume I Chapter X.

‡ Compares to 1975 local law enforcement agency total of 505,011.

§ Transportation cost represent an upper bound due to inclusion of HTGR HEU shipments.

cost of $580 million for a plutonium recycle LWR system or an approximately 1% increment on the total cost of all electricity in this time-frame. The same report estimates that in the absence of plutonium recycle, annual costs would be 25% less at $430 million.

Thus, there is no evidence that economic impact of safeguards on the consumer will be substantial. However, the impact on selected portions of the nuclear industry, such as reprocessing plants and recycle fuel fabrication plants, may reconsiderable. The accuracy of an estimate of this impact is fraught with uncertainties such as the specific process employed and the specific safeguards techniques deployed in protecting the SSNM.

4.10 DESIGN AND EVALUATION

Safeguards system designs in the U.S. are presently developed to meet the NRC regulations that are published in Title 10 of the U.S. Code of Federal Regulations. The implementation of these regulations for specific facilities is assisted by the use of U.S. NRC Regulatory Guides. The licensee or applicant submits a plan for compliance with the regulations which is then evaluated by the NRC staff. Except in those cases in which the applicant or licensee proposes an alternative method, the NRC staff utilizes the methods described in the guides in evaluating an applicant's or licensee's capability for and performance in complying with specified portions of the Commission's regulations. The Regulatory Guides are not, however, substitutes for regulations and a literal compliance with them is not required. Judgment by the NRC staff is the basis for resolving detailed licensing issues.

The future nuclear regulatory base in the U.S. is expected to be oriented toward a performance objective approach rather than a set of procedural requirements [4,74]. Consequently, a licensee will be judged not on the narrow basis of strict compliance with written regulations but on a demonstrable ability to control materials and protect his facility. This new approach to Safeguards of "performance requirements plus demonstrable capabilities equals adequacy" has received the support of industry . Regulation by performance objectives allows a facility operator the freedom of specifying the methods and approaches that will be applied to his possibly unique situation. On the other hand, the licensee must prove that his material is safeguarded and not just behind an 8 ft.

high fence with three strands of barbed wire, etc. Thus, on-site performance as rated by analysis, operational (black hat) evaluations, and on-site review will most likely be the key to operating licenses[4]. The performance objectives of (1) preventing with high confidence a civil disaster; (2) providing substantial protection against serious civil damage; and (3) providing timely and accurate information on the status of nuclear material and facilities must be shown to have been achieved in the operational sense.

Design of Integrated Systems

Recent studies on up-graded material accounting in model high-throughput fuel-cycle facilities (i.e. , reprocessing plant and mixed-oxide fuel fabrications plants) have shown that material accounting alone is not likely to meet all safeguards performance objectives at all areas of the model plants[26]. In a similar vein, a fortress concept of physical protection is not totally adequate since the amounts and locations of the material inside the facility would not be known. Thus fuel cycle facilities handling a high throughput of strategic special nuclear material will most likely require an integrated safeguards system design to meet performance objectives. The term "integrated" implies that overlaps, gaps, and interfaces between customary subdivisions of safeguards control and responsibility (accounting, access control, containment, physical protection, etc.) would be taken into account. Consequently, an effective prevention, deterrence, or detection of the total spectrum of threats involving the malevolent use of nuclear materials employs all aspects of safeguards systems.

A design concept for an integrated safeguards system can be summarized by the following procedures: identify all the perceived threats leading to theft and sabotage; identify the

necessary protective measures to counter these threats in accordance with system performance criteria; organize these protective measures into major subsystems for effective management and operation[75]. Information and data resources required to accomplish the design include system performance criteria, available protective measures and plant design features. The perceived threat, however, is the major driving force in developing an integrated safeguards systems design.

The threat, since it is central to determine the adequacy of safeguards, has received considerable attention at NRC '[76]. No simple, fixed, single answer appears to be appropriate for the question "What is the Threat?" A response that changes with time and accommodates the inherent uncertainty associated with the threat appears to be the only defendable response for the definition of this complex multi-dimensional parameter. The safeguards system design must behave well in the range of this uncertainty and not degrade catastrophically against larger and larger threats.

Evaluation

A necessary attribute of a regulatory operation based wholly or partly on performance objectives is a capability of consistently evaluating a safeguards system effectiveness. A recent ERDA report[77] has developed a general framework for evaluating safeguard system effectiveness in terms of the societal risk*. There are problems in quantifying all aspects of the societal risk, Particularly in determining the expected frequency of attempts[78] of deliberate destructive acts on nuclear facilities, however, the general structure and definition of terms has placed a clearer perspective and delineation of the over-all safeguards problem. The thrust of the developing evaluation methods is to place less reliance on an individual expert review to a more systematic/engineering approach.

* Societal risk is a concept that evolves from a generalization of reliability theory which has frequently been used in nuclear power safety studies. Societal risk describes the risk in terms of the frequency of attempts, times the probability of events occurring, times the consequences if they do occur.

The development of safeguards effectiveness methodology[79] has logically separated into two rather distinct phases:

1. **Techniques for identifying and enumerating potential adversary action sequences for the access and acquisition of SSNM**[79,80,81].
2. Quantification techniques to evaluate the probability of success of the identified adversary action sequences[79,80,82].

A successful development of these methodologies will aid the safeguards system designer in developing a truly effective safeguards system, will assist the facility operator in the conduct of trade-off studies such as

- costs versus security level
- guards versus hardware
- security versus operating flexibility

and would assist the regulatory agency in the evaluation of the adequacy of a proposed safeguards system.

NRC is supporting several research programs that "involves, mainly, the development of the methods, models and data necessary for assessing the effectiveness of existing and potential systems of safeguards." "The research to develop these methods of evaluating effectiveness involves definitions of objectives and of the related performance parameters -- for the safeguards system as a whole and for the various subsystems of which it is comprised." [52]

4.11 IAEA SAFEGUARDS RESEARCH

Until very recently, the Department of Safeguards and Inspections (DSI) of the IAEA consisted of an Operations Division and a Division of Development at which time a Division of Information Treatment was formed. The present Division of Development has a staff of approximately twenty-five people divided into the following three sections: System Studies; Methods and Techniques; Field Operations. In addition to staff salaries, the Division's actual 1975 obligations included approximately $144,000 in scientific and technical contracts, a relatively modest level of support that had remained almost constant for a number of years. Approximately $400,000 was committed for the purchase of scientific supplies and equipment, a significant portion of these funds being used in commissioning the Safeguards Analytical Laboratory at Sibersdorf, near Vienna.

For 1976 the adjusted budget for the Division of Development includes for scientific and technical contracts, $490,000 and for scientific supplies and equipment, $510,000. For 1977 the estimated budget for these items are $486,000 and $578,000 respectively. The substantial increase in funds available for contract research in safeguards reflects an effort to remedy both the low level of expenditures available in the past and an effort to place the IAEA in a stronger position in the critical years ahead.

Since its founding in 1957, the IAEA has benefited from technical experts from states with active nuclear power or research programs. These experts have assisted both the operations and development staff of DSI through meetings and advisory groups in the formulation of its own safeguards procedures and research projects and in the identification of new problems and areas for safeguards research and development. At

these Technical Working Group and committee meetings the Agency has addressed the procedures, instruments and techniques that it might use in safeguarding reactors, reprocessing plants, fuel fabrication plants and enrichment plants. In December of 1975, the first meeting of the Standing Advisory Group on Safeguards Implementation (SAGSI) was held. The group was formed to provide IAEA with technical advice on safeguards and is composed of one senior scientist from the UK, FRG, Canada, India, Japan, the USSR, and the U.S.

In an effort to implement the preambulatory paragraph of the NPT, "Expressing their support for research, development and other efforts to further the application of the IAEA Safeguards System .. by use of instruments and other techniques at certain strategic points", the United States and the Federal Republic of Germany, in particular, undertook safeguards research programs related to international safeguards. In the United States, the AEC/ERDA made available the technical spin-off from its domestic safeguards research and development program and provided the Agency with technical expertise. In support of the IAEA, the U.S. Arms Control and Disarmament Agency initiated in 1967 a safeguards research program that rose to an average funding level of approximately $500,000 per year. Initially, the funding for the German safeguards program was substantial but unfortunately it was severely reduced in 1971, apparently in response to criticism from German industry. Finally, in 1975 Canada undertook a major effort with the IAEA to improve the safeguards Instrumentation for the on-power refueled CANDU reactor.

With the growing public awareness of the dangers of nuclear weapons proliferation, Congressional support for improvements in IAEA safeguards has rapidly increased. This very substantial additional U.S. financial support as Gifts-in-Kind is now coordinated in the

International Safeguards Project Office, Brookhaven National Laboratory. The Program Plan for Technical Assistance to IAEA Safeguards reflects many of the urgent needs of the Agency and the direction which safeguards research will take in the next five years. The major task areas outlined in the January 26, 1977, draft report include:

1. Measurement technology
2. Training
3. System Studies
4. Information processing
5. Surveillance and containment
6. Support for field operations

For many of these tasks, funding has been approved and a schedule for completion of the work set. These programs will commit a total of over $2,000,000 for both FY 76 and FY 77.

It is reported that for FY 78 Congress is considering appropriations of approximately $10,000,000 to support and to strengthen IAEA safeguards. The need for strong support for the Agency's international inspection effort is almost universally acknowledged. However, this very large increase in funds on top of the large increases in funds authorized in FY 76 and FY 77 will place an especially heavy burden on ERDA's International Safeguards Project Office to make certain that these new monies will be wisely spent. This level of support will make possible the use of advanced technologies in attacking such problems as "timely detection" when timely may mean hours rather than weeks or months; the use of dynamic methods of inventory and control and the development of highly portable, versatile, non-destructive assay instrumentation for the precise measurement of uranium and plutonium in the field. These and equally difficult problems in the area of sur-

veillance and containment can be attacked on a scale not considered possible until now. As has been noted, money is essential, but outstanding technical competence and the highest levels of organizational skills will be required to ensure that this kind of support is effective. It is particularly important that the U.S. make every effort to convince all of the remaining nuclear supplier states that there is both a need and a role for their contributions.

ANNEX A

HOW LARGE A THEFT IS POSSIBLE WITHIN THE LEMUF?

The statistical notion of material accounting implies that when a theft is perpetrated, there is never an absolute certainty that it will be detected. The procedures used in the nuclear industry to generate a material balance involve an accounting based on measurements where the statistical variations in the measurement error are frequently comparable with the small discrepancies that it is desired to detect. Thus, when an operator or inspector "calls" that a material discrepancy exists, he is saying implicitly only that there is a chance that material has been removed, and is admitting that there is a finite expectation of a false alarm.

In order to estimate how large a theft might be perpetrated without significant chance of detection it is necessary to review the current formalism for calling accounting discrepancies. Given perfect procedures and measurements, and assuming no diversion, the material balance:

Inventory (BI) at beginning of period + Additions (A)

- removals (R) - Inventory (EI) at the end of period

is zero. In practice, because there are instrumental (and sometimes human) error in measuring BI, A, R and EI, the balance departs from zero, and this deviation is designated "MUF" or "material unaccounted for". Current NRC control procedures require that a discrepancy be called when the MUF exceeds a threshold of twice the expected standard deviation (2σ) of the

MUF. This threshold is called the LEMUF (limit of error of the MUF) and is computed using statistical techniques to combine the individual measurement errors to form the total error in MUF. If measurement errors are distributed normally with zero mean, the probability of a MUF being greater than this LEMUF threshold when no material is missing is approximately 5%*. The currently acceptable value of LEMUF (for the domestic case) or the overall standard deviation (for IAEA) are given in Tables 2.1 and 3.1 of the main text.

insight into how large a theft relative to the LEMUF is possible without substantial risk of detection can be obtained by again making the (not-unreasonable) approximation that the uncertainty in the MUF is distributed according to a "normal" error distribution as in the top illustration of Figure Al. In the absence of thefts** the expected value of MUF will be zero. Given a theft the expected MUF will be biased, so that the probability of the theft leading to a discrepancy call is increased. The lower graph of Figure Al shows how this probability increases with the magnitude of the theft (normalized to the standard deviation or LEMUF) for different decision criteria. Curve A shows the call probability based on application of the current NRC criteria (a discrepancy being noted when the MUF exceeds the LEMUF, which implies a .025 probability of a false call when no loss exists). Curves B and C show how the chance of detection might be increased by accepting higher (.05 and 0.1) probabilities of falsely calling a discrepancy in the absence of a theft. We should note that while more sophisticated data processing is in the exploratory phase, there are also more sophisticated ways of removing material. Nevertheless it seems that the risk of detection following the diversion of 0.25 of the LEMUF in a

---

*Half of the time the MUF will be positive, indicating a loss of material, and the other half of the time it will be negative, indicating a gain. Thus, the probability of falsely calling a loss discrepancy is only one-half of 5% or 2.5%.

**This discussion assumes the absence of unmeasured losses or gains.

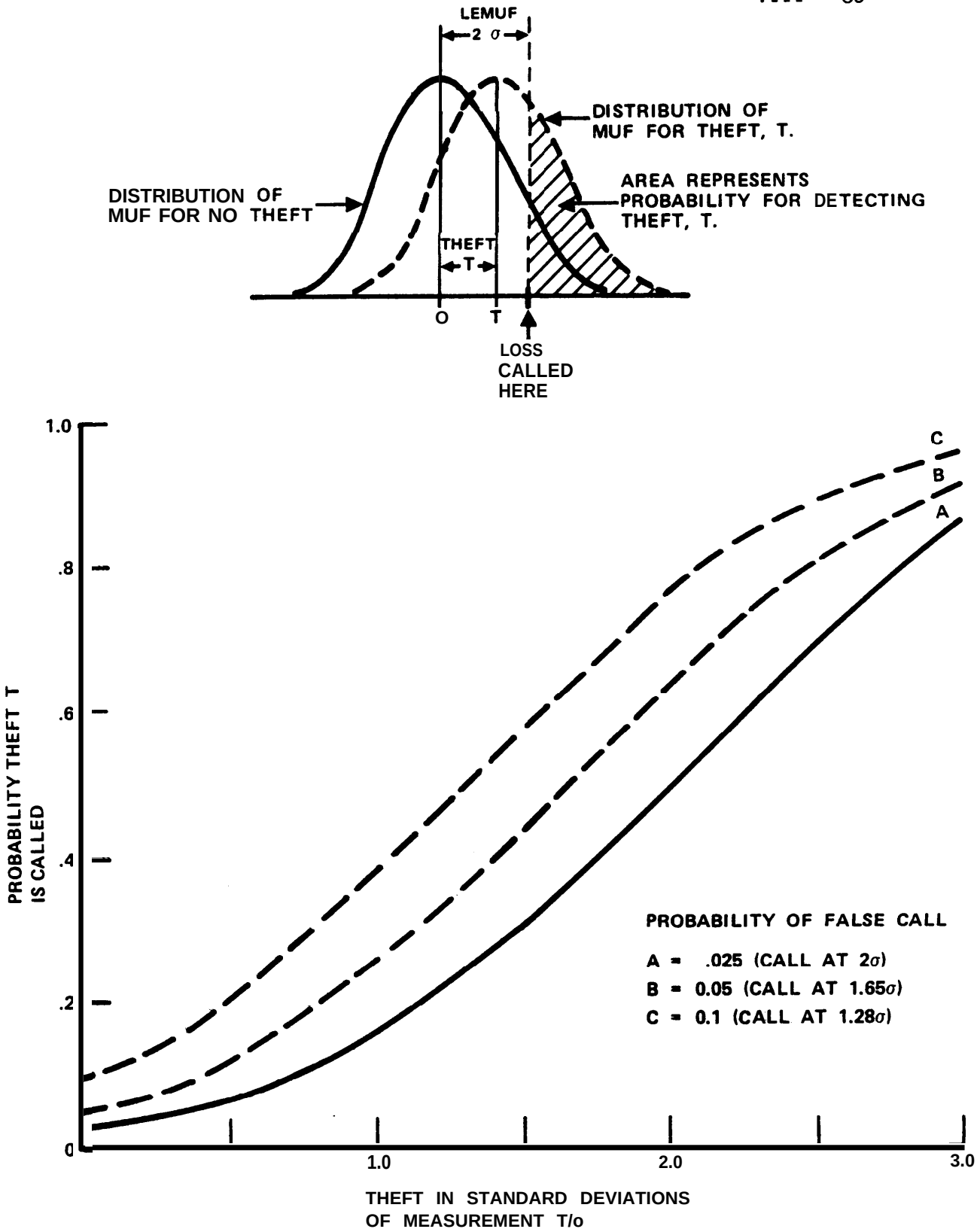

Figure A1. Capability of Accounting System for Detecting Theft at Various Levels of Confidence

single accounting period is small enough so that no authority would have confidence in making an accusation of theft based on accounting alone. A theft of one half the LEMUF stands a chance of one in four or five of detection; enough to give pause to the diverter who plans a long series of thefts, but probably insufficient to deter the one-time-only thief.

The above discussion has not taken account of efforts to resolve a discrepancy prior to "calling" a material discrepancy. Because the "calling" would undoubtedly entail added cost and inconvenience to the operator, there would likely be an effort to resolve the discrepancy. This raises the possibility of introducing an unsuspected bias. The varying degree of scrutiny applied to favorable and unfavorable numbers can introduce significant bias.

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Appendix IX. International Controls

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International Controls

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APPENDIX 1X-A

PURPOSE AND SCOPE OF THE REPORT

by

Stieff Research and Development Co., Inc.

PURPOSE AND SCOPE OF THE REPORT.

The Stieff Research and Development Company has been directed by the Office of Technology Assessment (OTA) to revise a draft report prepared earlier under a subcontract with the Stanford Research Institute on the roles which can be played by the International Atomic Energy Agency (IAEA), the European Atomic Energy Community (EURATOM), and the Nuclear Suppliers Conference, in limiting the future proliferation of nuclear weapons. In view of the short deadline under which OTA must operate, it was recognized that this report could not possibly analyze these subjects in depth. It was hoped, however, that the current status of these international initiatives could be summarized, and that some aspects of their non-proliferation roles not previously treated could be developed.

Within the last nine months there have appeared in the United States three comprehensive government publications (1, 2, 3) dealing directly with many of the issues covered in this report. They are:

1/ Nuclear Weapons Proliferation and the International Atomic Energy Agency.

2/ International Proliferation of Nuclear Technology.

3/ Assessment of U. S. and International Controls Over the Peaceful Uses of Nuclear Energy.

During this period the IAEA has issued two documents (4 and 5) on subject matter treated in this report. They are:

4/ IAEA Safeguards Technical Manual Introduction, Part A, Safeguards Objectives, Criteria and Requirements.

5/ Regional Nuclear Fuel Cycle Center Study, Institutional-legal framework aspects.

Also, the Commission of the European Communities issued on 22 September 1976 a new Commission Regulation (6) "concerning the application of the provision on EURATOM safeguards." This regulation codifies the safeguards regulations required to implement the IAEA-EURATOM Agreement which was concluded on 5 April 1973 as required by Article 3 (1) and (4) of the Treaty on the Non-proliferation of Nuclear Weapons. Finally, there is the White House statement by the President on nuclear policy (8) which was released on October 28, 1976. These recent references and the other documents and reports used in this review are cited under the List of References at the end of the report. In addition material has been obtained in the course of discussions with U. S. officials of the Energy Research and Development Ministration, the Nuclear Regulatory Commission, the Department of State, the Arms Control and Disarmament Agency, and officials of the U. S. Missions to the IAEA and EURATOM. Detailed discussions have also been held with officials of EURATOM in Brussels, and Luxembourg and with officials of the IAEA in Vienna.

APPENDIX IX-B

INTRODUCTION

by

Stieff Research and Development Co., Inc.

INTRODUCTION

Since the closing days of World War II the proliferation of nuclear weapons has been widely recognized as perhaps the most serious threat to the survival of mankind and the effort to limit this proliferation as a task which would test the wisdom, ingenuity, and statesmanship of the world's leaders. As governments and men have grappled with this problem, their concerns have enlarged to include not only what is now called "vertical proliferation" - i.e. , the continued testing, manufacture, and growth of evermore sophisticated arsenals of nuclear weapons by the five principal nuclear weapon states (NWS), but also the seriously destabilizing potential of "horizontal proliferation" by the non-nuclear weapon states (NNWS), and, much more recently, the growing nuclear threat posed by terrorist or other non-state adversaries not operating under the authority of any established national government. Although this report is concerned primarily with the international framework that has or may be constructed to deal with the problem of limiting "horizontal proliferation" and, to a much lesser extent, with the international response to the non-state adversary threat, the importance cannot be overemphasized of the impact of "vertical proliferation" on our non-proliferation efforts. Failure of the NWS's to reduce the immense present danger embodied in the continuing growth of their nuclear weapons arsenals will as surely impede our non-proliferation objectives as would the failure of the world community to promptly challenge the test of any nuclear device or the diversion of safeguarded nuclear materials by a non-nuclear weapon state. The bitter reaction of the NNWS during the 1975 non-Proliferation Treaty (NPT) Review Conference and the threat of Yugoslavia to withdraw from this Treaty because, in its view the United States and the Soviet Union in particular, had not fulfilled their solemn obligations under Article 6 of the NPT, are clear evidence that the non-nuclear weapon states do not take lightly their understanding of the balance of obligations undertaken by all parties to the NPT.

Introduction

The threat of “horizontal proliferation” has, of course, been recognized since the beginning of the Nuclear Era and was the object of the joint Declaration of November 15, 1945 by the President of the United States and the Prime Ministers of Canada and the United Kingdom. In this policy statement, the word, “safeguards” was used for the first time to describe international measures intended to prevent the use of nuclear materials and equipment from furthering any military purpose. The Declaration further proposed that the United Nations should set up a commission to make a number of specific proposals including “safeguards” to reassure states complying with a ban on nuclear weapons that violations or evasions of the ban had not occurred. The word “safeguards” is generally understood to be “a collective term that comprises those measures designed to guard against the diversion of material such as source and special nuclear material from uses permitted by law or treaty and to give timely indication of possible diversion or credible assurance that no diversion has occurred.” (9) For the IAEA, the use of material accountancy is considered to be the safeguard measure of fundamental importance, with containment and surveillance as important complimentary measures. (10) In the United States, the word “safeguards” has been broadened to include physical protection measures and penal provisions to deter theft and diversion.

Early U. S. nuclear policy was directed at the elimination of “vertical proliferation” and the prevention of “horizontal proliferation”. Unfortunately, efforts to establish the United Nations Atomic Energy Commission (UNAEC) and an International Atomic Development Authority (IADA) as proposed by Bernard M. Baruch, the United States Representative, were ultimately unsuccessful. The United States then turned to a policy of strict secrecy as the best means of limiting the spread of nuclear weapons. By the end of 1953, however, the United Kingdom and the Soviet Union had joined the

Introduction

group of nuclear weapon states and many countries were establishing nuclear research programs. These developments led to a major shift in U. S. policy and in December of 1953 President Eisenhower proposed his "Atoms for Peace" program in an address before the United Nations General Assembly. Through this approach it was hoped that the United States, by assisting foreign nuclear programs might not only influence the nuclear policies of other nations but also guarantee that, by the application of safeguards, the transfer of nuclear material and technology would be used only for peaceful purposes. With this address and with the enactment of the Atomic Energy Act of 1954 (42 USC 2011) establishing the basis of U. S. participation in international nuclear cooperative programs the necessity to address both aspects of nuclear proliferation became urgent matters of national policy.

The task of resolving "the Dilemma of the Fissionable Atom" - the unavoidable production in the peaceful application of the fission process of new fissionable material which could be diverted for weapons use - had not been ignored in the earlier efforts to establish the UNAEC and the IADA. The United Nations General Assembly Resolution laid down two principles:

1. "the fruits of scientific research should be made available to all nations and that the freedom of investigation and the free interchange of ideas are essential to the progress of knowledge."

2. "effective safeguards by way of inspections and other means to protect complying states against the hazard of violation and evasions," are essential.

Introduction

In its first report to the United Nations made almost thirty years ago the UNAEC included the findings on safeguards of its Scientific and Technical Committee. This report considered in more detail the problems of safeguarding declared nuclear activities, the detection of clandestine or undeclared nuclear activities, the seizure of nuclear materials, and the broad rights and privileges which an international control agency would require in order to implement effective safeguards. These principal policy areas still occupy those government officials and technical experts concerned with the problem of limiting the spread of nuclear weapons. With regard to safeguards, the UNAEC concluded that safeguards were scientifically, technologically, and practically feasible to the extent necessary to insure that atomic energy is used only for peaceful purposes. In addition, it was the Commission's belief that effective control of peaceful uses of atomic energy was dependent on the effective control of the production and use of uranium, thorium and their fissionable derivatives. On the specific need for international safeguards the UNAEC concluded that:

> "Only by such an international system of control and inspection can the development and use of atomic energy be free from nationalistic rivalries with the consequent risk to the safety of all people. Only by such a system can the benefits of widespread exchange of scientific knowledge and of the peaceful uses of atomic energy be assured. Only such a system of control and inspection would merit and enjoy the confidence of the people of all nations."

The issue of "horizontal proliferation" inherent in the decision to greatly expand the peaceful uses of atomic energy was squarely joined. The right of each nation to fully benefit from this potential source of almost limitless energy should be assured, but, at the same time, the essential conditions had to be established that each nation should foreswear the military uses of atomic energy, and that each nation must relinquish

at least those minimum sovereign rights necessary to assure its neighbors and the world that its non-proliferation pledge had not been violated.

On many occasions in the past twenty years, the concern felt for non-proliferation has yielded to potentially more dangerous problems requiring immediate attention. With the detonation of the Indian nuclear device in May of 1974, however, and with the rapid growth of nuclear power in many countries, the issue of non-proliferation has re-immerged as a prime topic of international policy. This fact is attested not only in the Legislative and Executive Branches of the United States Government, but also in the legislatures and foreign offices of many of the other capitals of the world. These events, the rising threat of nuclear terrorism and sabotage, major unanswered questions of an environmental nature, and challenges to the safety of nuclear facilities have all called into question the viability and feasibility of continued nuclear power development. Questions are now being raised in many quarters concerning the effectiveness of the international institutions that were put into place in the late 50's and the 60's to deal with the problem of "horizontal proliferation." Many alternative approaches are now being considered to these questions ranging from moratoriums on nuclear exports and the construction of nuclear power stations to multinational fuel centers. The complexity of the social, economic, political, military, and technological issues which surround the proliferation problem absolutely guarantees that a simple solution to this matter will not be found.

A broadly based non-proliferation policy must contain many elements and should start with the recognition that for some countries there does not seem to be a reasonable alternative to nuclear power. This means that whether or not the United States withdraws from the nuclear export market or whether the United States chooses alternate sources of power, our national security will be directly affected by the

decisions and actions taken by other countries in the nuclear area. The United States already has contractual commitments with many countries to provide nuclear fuel and these countries must be assured that their economies will not be disrupted by the withdrawal of U. S. enriched uranium. Our allies, in particular, and all non-nuclear weapon states, must be assured of strong alliances which will protect them from military or nuclear threat, The nuclear weapon states must acknowledge the necessity for real progress in the negotiations to limit the testing and growth of nuclear weapons. Sustained efforts should be made to increase the number of countries which are parties to the non-Proliferation Treaty and positive incentives should be offered to those countries which are party to the Treaty. There should he a clear understanding that abrogation of the Treaty or attempts at the diversion of nuclear material will be met with immediate world disapproval and strong sanctions. The intelligence agencies, particularly those of the nuclear weapon states, should significantly increase their efforts to insure that if clandestine nuclear facilities are constructed, they will be detected. Cooperation in the intelligence field even between our closest allies presents difficult problems but this subject should be carefully examined, and, if possible, formal procedures established to ensure the timely exchange of essential information. A strong effort should be made to persuade all countries that the limiting of the spread of nuclear weapons is in their best interests, for any country may be held hostage by a diversion or theft which occurred on the opposite side of the world. The international institutions which have been established to monitor compliance with the non-proliferation obligations of the non-nuclear weapon states should be strengthened and the member states of these organizations should insist on effective and credible, not minimal safeguards. Finally, our determination to contain the spread of nuclear weapons must not weaken even if another non-nuclear weapon state should successfully test a nuclear device. Nor, should the inability of our international institutions and initiatives to meet unrealistic expectations lead us to abandon them as failures, but rather, we must set reasonable goals and then make certain that they are met.

APPENDIX IX-C

THE INTERNATIONAL ATOMIC ENERGY AGENCY AND INTERNATIONAL SAFEGUARDS

by

Stieff Research and Development Co. , Inc.

THE IAEA AND INTERNATIONAL SAFEGUARDS

A. THE STATUTE, THE LEGAL FRAMEWORK.

On the 23rd of October 1956 the Statute of the International Atomic Energy Agency (11) was approved by the Conference on the Statute of the International Atomic Energy Agency at the headquarters of the United Nations. The Statute was opened for signature on the 26th of October 1956 and came into force on the 29th of July 1957. In order to clearly understand the Agency's safeguards objectives, its authorized safeguards functions, and the legal framework for the Agency's safeguards, responsibilities and rights, some familiarity with the Statute is necessary. The appropriate safeguards related Articles from the Statute are summarized below and in full in Annex A. The entire statute has been reprinted in "FACTS ON NUCLEAR PROLIFERATION, A HANDBOOK" (12).

The objectives of the Agency are defined in the Statute under Article II which provides that the Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world and that so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose.

The Safeguards functions are defined in the Statute under Articles III, AS and B2 which authorize the Agency to establish and administer safeguards on special fissionable and other materials, services, equipment, facilities, and information made available by the Agency, and to apply safeguards, at the request of the parties, to bilateral or multilateral arrangement, or at the request of a State, to any of that State's activities in the field of atomic energy. Thus, this Article provides for the application of safeguards to declared nuclear facilities as opposed to the full fuel cycle safeguards of the NPT and permits a State to operate an indigenous, undeclared nuclear facility without IAEA safeguards. For example, the Indian nuclear facilities used to

produce the plutonium used in their first nuclear test were not under IAEA safeguards although other facilities had been declared and were safeguarded by the IAEA.

Article III B-2 provides for Agency control over the use of special fissionable materials which has been received by the Agency, for its own projects or projects with other states in order to ensure that these materials are used only for peaceful purposes. Article XI F-4 requires that such projects shall be subject to the safeguards provided for in Article XII, the relevant safeguards being specified in the agreement.

The Agency's safeguards, responsibilities and rights are specified in the Statute under Article XII. This very important Article should be examined closely. However, in summary, it provides for the following:

XII Al.- Design review of facilities and equipment to permit effective application of the safeguards.

XII A2.- Observance of any health and safety measures prescribed by the Agency.

XII A3.- Maintenance and production of operating records.

XII A4.- Submission of progress reports.

XII A5.- Approval of the means to be used for the chemical processing of irradiated materials, the requirement that the special fissionable materials recovered or produced. as a by-product under continuing Agency safeguards, and the deposit with the Agency of any excess of any special fissionable materials recovered or produced as a by-product over what is needed for the above-stated uses in order to prevent stockpiling of these materials. This unused Article has recently received considerable attention

in connection with the establishment of Regional Nuclear Fuel Cycle Centers. The provisions of this article have assumed particular significance in view of the enormous amounts of plutonium that will be produced by nuclear power reactors in the 80's and the danger that would follow from the diversion of even a relatively small amount of this stockpile for weapons purposes. These "approval" and "deposit" provisions of the Statute when coupled with the concept of a Multinational or Regional Nuclear Fuel Cycle Center (RNCC) should offer an acceptable solution to what is otherwise a very difficult and potentially dangerous problem.

XII A6.- Dispatch of Agency Inspectors into the territory of the recipient State who shall have access at all times to all places and data and to any person who by reason of his occupation deals with materials, equipment, or facilities which are required by this Statute to be safeguarded, and the determination of compliance with the undertaking between the Agency and the State against use in furtherance of any military purpose.

XII A7.- The recipient State or States to take requested corrective steps within a reasonable time, suspension or termination of assistance and withdraw any materials and equipment made available by the Agency or a member in furtherance of the project in the event of non-compliance.

XII B.- Establishment of a staff of inspectors.

XII C.- Verification of records and reports. This Article also provides that the inspectors shall report any non-compliance to the Director General who shall thereupon transmit the report to the Board of Governors. If the State or States fail to remedy forthwith any non-compliance which it finds to have occurred, the Board is required to report the non-compliance to all members and to the Security Council and General Assembly of the United Nations.

The Board may also direct curtailment or suspension of assistance being provided by the Agency or by a member, and call for the return of materials and equipment made available to the recipient member or group of members. Finally, the Agency may also, in accordance with Article XIX, suspend any non-complying member from the exercise of the privileges and rights of membership. The actions noted above represent the range of sanctions permitted by the Statute in the event of a non-compliance and failure by a member State to take the requested corrective action. The need for stronger sanctions by the nuclear supplier states, at least, is obvious.

The safeguards activities of the IAEA are explicitly directed at the problem of "horizontal proliferation", i.e., a decision by a non-nuclear weapon State to divert special fissionable materials to further a military purpose. Diversion is defined in the first document approved by the Board of Governors on the 31st of January 1961 describing the Agency's safeguards (13) to mean:

"...the use by a recipient State of fissionable or other materials, facilities or equipment supplied by the Agency so as to further any military purpose or in violation of any other condition prescribed in the Agreement between the Agency and the State concerning the use of such materials, facilities or equipment."

It is clear from the Statute, from this description of the Agency's Safeguards System and all subsequent Agency safeguards documents, that the Agency is not legally authorized to address the problem of the terrorist or the non-state adversary nor, of course, the question of "vertical proliferation"- Those functions not explicitly authorized by the Statute are reserved to the State. The IAEA does not

have police powers and it cannot prevent a diversion of nuclear materials to some military purpose. The Statute is also silent on the closely related problem of physical security. The Agency's activities in this area will be treated separately in this review but it should be stressed here that the Agency does not have the statutory authority to make even a recommendation in the area of physical protection. In the Agency document entitled "THE PHYSICAL PROTECTION OF NUCLEAR MATERIALS" (14) it is noted under Section 2. Objectives, that:

> "The Agency has no responsibility either for the provision of a State's physical protection system or for the supervision, control or implementation of such a system. The Agency may informally advise the State on the results of observations made during its normal safeguards activities. Further assistance by the Agency will be provided only when so requested by the State."

Finally, it is important to note that the Statute does not address the problem of the detection of clandestine facilities; a very important matter, as has been noted, which was included in the 1946 Report of the Findings of the Scientific and Technical Committee of the UNAEC. This decision would appear to reflect the conscious omission by the States of this activity because, of necessity, any intelligence activity would constitute an unacceptable infringement of the sovereign rights of the State. Therefore, this essential element of any comprehensive non-proliferation policy must remain the responsibility of the intelligence agencies of the individual States, although cooperation in this sensitive area would clearly enhance the deterrent aspect of such efforts.

IAEA and International Safeguards

Although many States now accept the arrival of an international inspector at their borders as a routine matter it should be remembered that the safeguards Provision of Article XII, less than twenty years old, represents a watershed event in the field of international treaty verification and a major first step in the relinquishment of a State's sovereign rights to a higher need and authority. The very broad inspection rights of Article XII, A-6 which provided for "access at all times to all places and data and to any person" have not been repeated even in INFCIRC/26. This description of the Agency's Safeguards System includes a table of frequency of routine inspections; a response both to the concerns of the State and the practical problems of staffing and inspecting research reactors. The acceptance of the principle of international inspection extends well-beyond the proliferation of nuclear weapons and suggests that the treaty verification problems of other arms control agreements might yield to similar approaches.

There have been a number of suggestions in the past that, if the Agency is unable to undertake important new duties or responsibilities which are not authorized in the Statute, then the Statute should be amended to provide the legal basis for these new functions. This course of action, however, will not necessarily produce the desired results. Officials familiar with the operation of international organizations and with recent world political developments caution that the opening of the Statute to amendment can result in major changes which are not desirable and which may reduce rather than enhance the role of the organization. The establishment of a well-developed consensus and a carefully prepared agenda should precede any decision to amend the Statute of the International Atomic Energy Agency.

IAEA and International Safeguards-B.

B. MEMBERSHIP, ORGANIZATION, AND FINANCE

Membership. The Director General of the IAEA, Dr. Sigvard Eklund, in his report to the Twentieth Session of the General Conference of the International Atomic Energy Agency in Rio de Janeiro, September 1976, stated that:

> "Since 1957 the number of member States has grown from 60 to 109 with a corresponding increase in attendance at the General Conference. The Agency's executive body, the Board of Governors, now has 34 members compared with 23 in 1957 and 25 in 1963. The regular budget has increased as a result of growing activities, inflation and exchange rates from just over $4,000,000 in 1958 to $37,000,000 in 1976. The staff of the Agency has increased from 400 in 1958 to 1200 now."

The list of the Member States, which now totals 110, is given in Annex B.

Organization. The Organization Chart shown in Figure 1. for the International Atomic Energy Agency is taken from "The Agency's Program for 1977 - 82 and Budget for 1977 (15). Not shown in the Organization Chart is the Scientific Advisory Committee which reports to the Director General and the recently established Standing Advisory Group on Safeguards Implementation (SAGSI) which also reports to the Director General. SAGSI is currently considering the problem of more effective reporting to the Board of Governors and to the Member States of the results of the Agency's safeguards operation.

In Figure 1, it may be seen that the Department of Safeguards and Inspections (DSI) is currently divided into the Division of Development, the Division of Operations and a group for Information Treatment. These three subdivisions report directly to the Inspector General, Dr. Rudolph Rometsch. The Director General is now considering a

ORGANIZATIONAL CHART

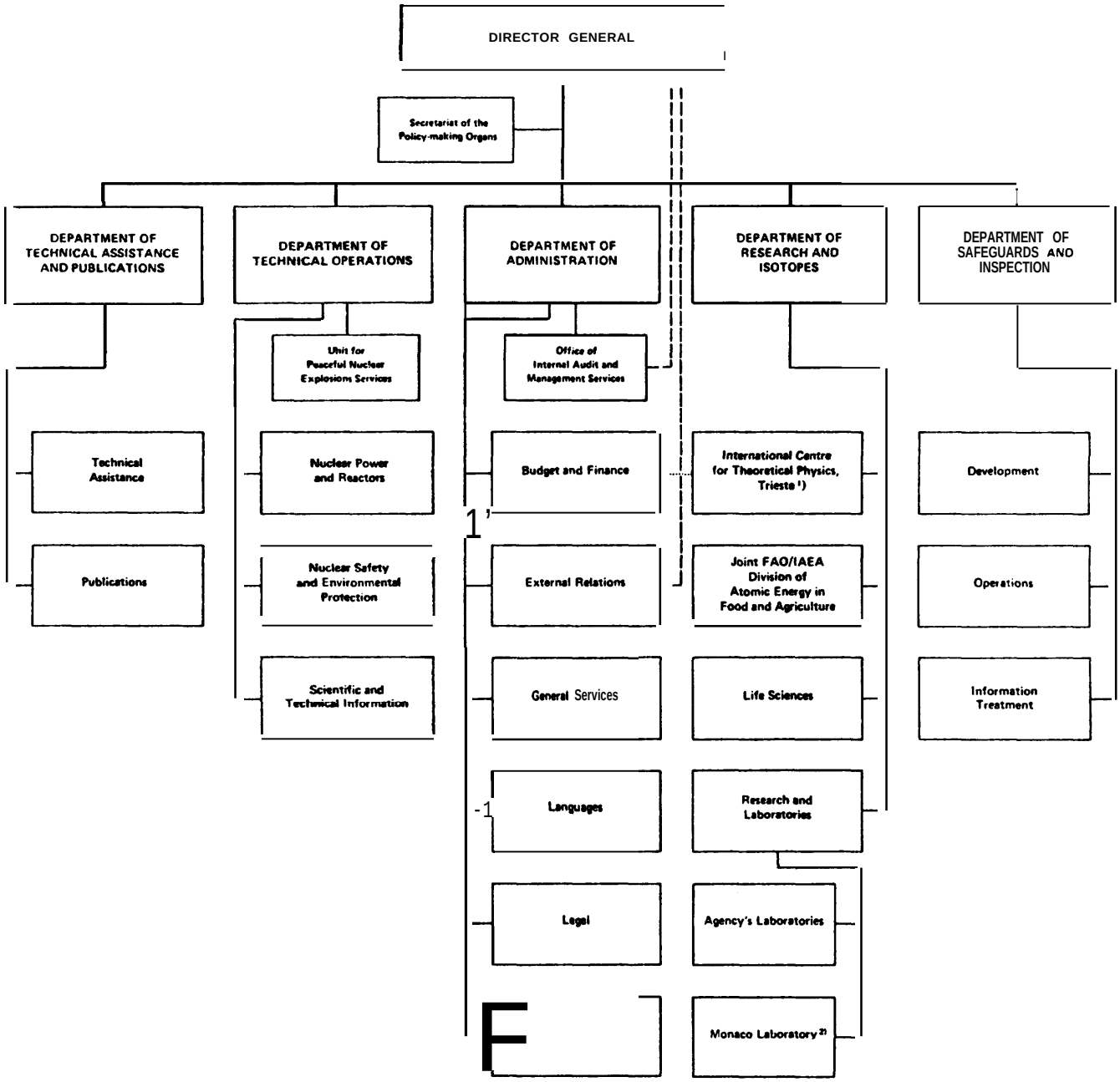

Figure 1.

Office of the Inspector General
R. Rometsch – Inspector General
(H. Seitl)
E. Burkert
E. Siedl
S. Hobden

Section for Standardization and Administrative Support
B. Sanders (Head)
R. Shroff
H. Seitl
E. Haegglund
V. Pettik
M. Hasan
V. Brown
J. Schuller

DIVISION OF DEVELOPMENT
A. von Baeckmann – Director
T. Ambrus

Section for System Studies
D. Tolchenkov (Head)
J. Lovett
M. Honami
Y. Panitkov
S. Wakamatsu 3/
K. Frauenberger
A. Schiffmann

Section for Methods and Techniques
A. Waligura (Head)
B. Clark
N. Beyer
M. de Carolis
E. Dermendjiev
A. Keddar
Ye Konnov
s. Sanatani
G. Boese
Me Siwy
1. Umar

Section for Field Operations
G. Hough (Head)
T. Beetle
E. Szabo
V. Sukhoruchkin
D. Terrey
H. Garbsch
C. Hagerty

Section for Account and Reports
C. Buechler (Head)
I. Hutchinson
O. Lendvai
W. Scherzer
M. Jesenko
R. Mahrenberger
C. Broskovic

Regional Section I South and South East
J. Beranek (Head)
R. Diaz-Duque
I. Hiramatsu
D. Petrunin
G. Rabot
R. Schaer
R. Ekarv
K. Sanders
S* Turel
CO Delegard
CO Kummer
G. Reset schnig

Regional Section II Americas
W. Frenzel (Head)
A. Massera
G. Rubinstein 2/
I. Todorescu
H. Gonzalez-M.
J. Kaniewski
B. Lee
G. Martinez-Garcia
V. Narang
W. Theis
O, Zoch
A. Moncada
Jo Clarke
1. Eberhart
B. Lefebvre

DIVISION OF OPERATIONS
S. Nakićenović – Director
J. de Groot

Regional Section II Central and Northern Europe
V. Fortakov (Head)
M. Ferraris
A. Janikowski
H. Kawamoto
V. Poroykov
J. Hornsby
A. Lumetti
L. Oudejans
V. Slizov
E. Woelfl
R. Stanzel
J. Henderson

Regional Section IV Far East
L. Thorne (Acting Head)
E, Kerr
D. Ahimsa
C. Lin
P. Noir
W. Payne
A. Ramalho
T. Rosescu
W. Alston
u. Barda
H. Frittum
N. Harms
E. Yellin
I, Stoiber
A. Katter
R. Henke

INFORMATION TREATMENT
V. Shmelev – Head
S. Booty
G. Farris
W. Gmelin
A. Roumiantsev
M. Miah
G. Russinov
J. Nardi 1/
S. Onnen 1/
J. Wooten 1/
M. Uhlir
B. Futschek
E. Bayona
H. Karpiuk
M. Asunta-J.
C. Arachchi
M. Bakardjiev
D. Schweiger
M. Tarko

Regional Section V Euratom
S. Thorstensen (Acting Head)
J. Wilson
B. Agu
H. Rose
H. Werner
I. Mishev
D. Perricos
M. Yousif
S. Curzon-Howe

1/ Cost free expert
2/ Temporarily assigned to SSAS
3/ Cost free trainee

Figure 2.

re-organization of DSI which will result in four divisions: Development, two Operational Divisions, and a Division of Information. Pending approval of this re-organization by the Board of Governors a new EURATOM section which will form the nucleus of the second operational division was established on the 15th of October 1976.

A more detailed presentation of the organization of the Department of Safeguards and Inspections is shown in Figure 2. In the Manning Tables of the 1977 Agency Budget, DSI has a total of 138 authorized positions for the year 1976 of which 102 are professional and 36 are GS Ratings or subprofessional. The number of established posts for 1977 show a total of 161 positions of which 111 are professional and 50 are GS. The preliminary estimate for 1978 is a total staff of 179 with 122 professionals and 57 GS positions. These changes in staffing reflect the anticipated increase in inspection activity resulting from the implementation under NPT of the IAEA-EURATOM and Japanese Safeguards Agreement as well as the United States and United Kingdom safeguards offer.

A recent internal analysis of the distribution of nationalities in DSI as of 1 March 1976 shows that of a total of 43 inspectors, in the Division of Operations, only 3 were U.S. nationals, whereas in the Division of Development 6 of the 20 professionals were U. S. citizens. In general, the IAEA personnel policy attempts to balance the available positions within the Agency among the different nationalities of the States of which it is composed. Information on the name, nationality and grade of each professional and support staff by department and division is published annually in the Agency publication INFCIRC/22. (16) An analysis of the information included in INFCIRC/22/REV.15 published in June of 1975 shows that approximately 18% or 68 of the total professional staff of 378 were U. S. nationals. It can be seen from this that the ratio of U. S. nationals in DSI is reasonably close to the overall ratio for the Agency, although for the Operations Division

it is approximately 6%; a figure considerably below the norm. The relatively low number of U. S. nationals in the Operations Division is a source of concern because, in general, U. S. nationals have performed very well and the Division needs staff with high technical competence, strong motivation and a commitment to painstaking and difficult work. An additional source of concern is the refusal of many countries to accept as inspectors nationals from other countries because of language or political consideration. The Director General specifically addressed this issue in his speech to the General Conference in September of this year when he said:

> "I wish to make an appeal to the States which have accepted our Safeguards System: Please accept also our inspectors irrespective of their nationality. We are now sometimes facing a situation where Country 'A' may accept an inspector from Country 'B' but 'B' not from 'A'."

The effective use of Agency inspectors is materially influenced by this type of action on the part of the member States. A remedy could be rapidly effected if it was the desire of the member States to do so. The problem can be more fully appreciated if one refers to the list of inspectors, the countries to which they are accredited, and the inspectors designated as Country Officers which is regularly published by the Department of Safeguards and Inspections.

In the evaluation of the effectiveness of international safeguards those issues which involve the inspectors are often overlooked in favor of legal, technical, or financial matters. In practice, the inspector will probably determine the success or failure of the safeguards effort. For example, special policies might be established for the hiring and retention of the inspection staff. After a fixed probationary period the Department should have the option to encourage a career decision in the field of safeguards inspection

by offering a long-term contract. The Department should also be free to terminate an inspector at the conclusion of the probationary period should his performance not meet Department standards without the political pressure which is often brought to bear in these matters when an international organization is involved. As part of the career development of the inspector, it is essential not only to maintain but to improve his proficiency by attendance at both established and special training programs. The Department is also faced with special problems of promotion and salary scales when compared with the professional requirements and duties of the staff members of other departments of the Agency.

Finally, and perhaps the most intangible, is the question of maintaining inspector morale when faced with difficult and sometimes dangerous working conditions, long and arduous periods of travel away from the Headquarters and his family, and the uncertainty that the work to be done is, as he has been told, really a matter of vital importance to the peace and security of the world. The responsibility for sustaining the inspector's morale does not stop at the desk of the Inspector General, but involves political and personal relationships at many levels within the Agency. The Agency' morale can in fact be profoundly affected by events which occur in other parts of the world. For example, the failure of the United States and the Soviet Union to take strong and unequivocal positions following the test of the Indian nuclear device in May of 1974 deeply affected the staff and the silence which followed that explosion still haunts the halls and offices of the IAEA.

Finances. Of the adjusted budget for 1976 of $37,002,000 the Department of Safeguards and Inspections required $6,443,000. Of this amount, $3,180,000 was obligated to salaries and wages; of the remaining $3,263,000 common staff costs accounted for $917,000; travel $410,700; scientific and technical contracts $490,000; scientific supplies and equipment $510,000; laboratory services $496,000 and supporting 'services,

meetings and miscellaneous $440,000. The detailed costs of the safeguards program is given in Annex C. Table I shows the safeguards cost in relation to total Agency expenditures under the Agency's budget 1971 through 1976. The estimated budget for DSI in 1977 is $7,951,000. The preliminary estimate for 1978 is $9,111,000. (15)

TABLE I

SAFEGUARDS COSTS
IN RELATION TO TOTAL AGENCY EXPENDITURE
UNDER THE AGENCY'S BUDGET 1971-76

Year	Safeguards costs (us $ 000)	Total Budget (us $ 000)	Safeguards Costs in percent of Regular Budget
1971	1 636	14 010	11.7%
1972	2 035	16 532	12.3%
1973	2 564	19 881	12.9%
1974	3 441	25 064	13.7%
1975	04 802	29 675	16.2%
1976	6 443	34 702	18.6%

IAEA and International Safeguards-B.

In 1971 it was decided that the safeguards costs should be adjusted in order to take account of the position of the countries with lower per capita incomes. Developing Member States whose base rate of assessment for 1971 was 0.04% of the Agency's budget pay an annual share of safeguards expenses of about $750.00. The 34 industrialized Member States bear 95% of the safeguards cost, while the remaining 72 members contribute 5%. The Board of Governors has recommended and the General Conference has adopted this year a resolution that will freeze at their present levels the contributions of the developing countries to the safeguards budget. The freeze will last from 1977 to 1980. The Director General in his speech before the General Conference suggested that:

> "this period should be used to re-examine the basic principals for financing the costs of safeguards and to establish a sound system that takes into account both the principals that every member state should contribute towards safeguards expenses and the recommendations of the NPT Review Conference to lighten the burden on the developing member states."

In response to the growth of nuclear power throughout the world and the greatly increased safeguards responsibilities of the Agency, the Department of Safeguards and Inspection has in the last ten years grown faster than any other department. With the implementation of the IAEA-EURATOM and Japanese Safeguards Agreement and the implementation of the United States and the United Kingdom offers to place their nuclear facilities not related to military uses under IAEA Safeguards, this trend can be expected to continue. In the opinion of some officials the limitations on the Agency's ability to implement its safeguards responsibilities will not be due to financial constraints but, rather, the limitations will be of a political nature and will reflect the attitudes and the determination of the member states, both nuclear and non-nuclear, to support credible effective safeguards.

IAEA and International Safeguards-B.

In addition to the assessed contributions to the Agency budget the United States has, beginning in 1974, undertaken a program to strengthen Agency safeguards by the provision of gifts-in-kind. In the Foreign Assistance Act of 1975 approximately $200,000 was identified for support of Agency safeguards. Initially, in FY 1976 an additional $300,000 was made available through the gifts-in-kind and that amount was subsequently increased by $1,000,000 (the Glenn Amendment) as Congressional concern for the effectiveness of Agency safeguards has grown. In FY 1977, $1,600,000 has been authorized including the first increment in a $5,000,000-five-year-program has also been authorized. Officials of the United States Government and the IAEA met during the first two weeks of November to coordinate a long-term program to strengthen the Agency's program including; major improvements in the Agency's safeguards data management and data analysis programs, substantial increases in the in-training programs for Agency inspectors, the provision of technical experts in many areas, the development of improved instrumentation for the non-destructive nuclear measurements, and the development of improved surveillance and containment devices.

It is reported that the Federal Republic of Germany has also made an offer of gifts-in-kind to the Agency of approximately $300,000 for the coming year. It is important that the other nuclear suppliers and the Soviet Union also join in this effort to meet the technical and financial needs of the Agency's safeguards program in the critical period ahead. If the principle of international inspection is to be widely accepted, the Agency's Safeguards System must not be a creature of United States Policy nor should it even appear to be so.

IAEA and International Safeguards-C.

C. **NON-NPT OR FACILITY SAFEGUARDS.**

Information Circular/26. The safeguards described in Article XII of the Agency's Statute were intended by the drafters to be only a framework for the actual IAEA's Safeguards System. (17) The fleshing out of that framework and the detailed elaboration of safeguards procedures and techniques that have been developed over the past twenty years has been accomplished by the joint efforts of the Division of Safeguards and Inspections and a large number of experts from the Member States who have participated in both formal and informal technical meetings held at the Agency and elsewhere. In the early stages of the evolution of the IAEA Safeguard System the Agency was concerned only with the safeguarding of research, tests and power reactors with less than 100 (MWT) megawatts thermal output, the source and special fissionable materials used and produced in these reactors, and the small research and development facilities.

The first document outlining the Agency's Safeguards System for use with research reactors was approved on the 31st of January 1961 by the Board of Governors and has been published by the Agency as Information Circular/26 (18). This document is reproduced in Annex D. INFCIRC/26 is of interest historically because it established a pattern for the organization and content of subsequent Agency safeguard documents. The Introduction, Paragraph 3 specified:

> "Agency Safeguards will be applied to materials and facilities voluntarily placed under Agency safeguards by a State or States. Where two or more States request the Agency to administer the safeguards provisions of an agreement between those States, the Agency will apply those provisions provided that they are consistent with the procedures laid down in this document. The administration of safeguards

> by the Agency under this Paragraph shall be governed by an agreement pursuant to the Statute between the Agency and the State or States concerned which shall be made for a specific period."

In Paragraph 4 of the Introduction it is stated that:

> "procedures covering other types of nuclear facilities will be developed as the probable need for them becomes evident. In regard to produced material the safeguards provided for this document relate only to the first generation of produced material."

From the Statute as well as the Introduction of INFCIRC/26 it is clear that the Agency's intent was to develop a facility specific safeguard system, that safeguards were to be applied to both materials and facilities voluntarily placed under the Agency's System, that the Agency's facility safeguard would evolve as the need developed, that the agreements would be made for a specific period, that an agreement between the State and the Agency would govern the safeguards applied by the Agency and, finally, the Agency's Safeguards System was to be reviewed after a period of two years in order to evaluate the experience gained by the Agency as well as the technological developments which had taken place during the interval.

Two of the items in this list, in particular, those relating to pursuit of produced fissionable material past the first generation and a specific date for the termination of a safeguards agreement have become sources of difficulty in the last few years. As understanding of the problems involved in safeguarding a fully developed nuclear fuel cycle have increased, it has become clear that both of these weaknesses offered a legal route for the acquisition of unsafeguarded fissionable material. The final

item is also significant because it reflected an awareness on the part of the Agency even then that their safeguards procedure would continue to evolve in the response to technological change and that they should be continuously reviewed in the light of actual experience. Some of the criticism of the Agency's safeguards procedures, while well founded, does not take into consideration this evolutionary aspect. Because, practice may fall far short of expectations in the early stages, disillusionment sets in and leads to the conclusion that because safeguards at some point are inadequate they cannot be made to succeed either in theory or in practice.

Information Circular/66/Rev.2.

The first major change in facility specific safeguards occurred in 1964 when the Agency Safeguards System was extended to include large power reactors. INFCIRC/26 and Add. 1. (19) Subsequently, following a review of the Agency's System, a revised document, THE AGENCY'S SAFEGUARDS SYSTEM, INFCIRC/66, which describes the IAEA Safeguards System now in use for those States which have not ratified the NPT, was approved by the Board of Governors. This document was provisionally extended in 1966 to include Annex I, "Provisions for Reprocessing Plants", (21) The final extension occurred in 1968 with the addition of Annex 11, "Provisions for Safeguarding Nuclear Material in Conversion Plants and Fabrication Plants". (22) This document has been reprinted in full as Annex II in the Government Publication (1; op.cit.) "NUCLEAR WEAPONS PROLIFERATION AND THE INTERNATIONAL ATOMIC ENERGY AGENCY". Some of the more important provisions are reproduced in Annex E.

In the Introduction to INFCIRC 66/Rev. 2 can be seen a continuation of those trends which first appeared in INFCIRC/26. Concern for the impact of safeguards on the States' nuclear industry becomes even more explicit. For example, under B. General Principles of the Agency's Safeguards, The Agency's Obligations include the following:

IAEA and International Safeguards-C. ’

9. Safeguards shall avoid hampering a State’s economic or technological development.

10. Safeguards must be consistent with prudent management practices required for the economic and safe conduct of nuclear activities.

11. The Agency may not request a State to stop the construction or operation of any principal nuclear facility except by explicit decision of the Board.

13. The Agency shall take every precaution to protect commercial and industrial secrets and no member of the Agency’s staff shall disclose, except to the Director General and to such other members of the staff as the Director General may authorize.

“17. The principal factors to be considered by the Board in determining the relevance of particular provisions of this document to various types of materials and facilities shall be the form, scope and amount of the assistance supplied, the character of each individual project and the degree to which such assistance could further any military purpose. The related safeguards agreement shall take account of all pertinent circumstances at the time of its conclusion.”

Part III. Safeguards Procedures, still provides in Paragraph 29 for safeguards procedures which are to be applied to nuclear materials as well as the facilities containing or to contain such materials.”

The States’ concerns that information provided in the design review might compromise their industrial secrets or unnecessarily infringe on their sovereignty is reflected in the revisions which appear in Paragraph 30 and 32 where the sole purpose of such a review is the effective application of safeguards.

The Agency is enjoined not to publish or communicate to any State, organization or person information obtained in connection with the implementation of safeguards. Specific information, however, may be given to the Board or to such Agency staff members as required by reason of their official duties. In addition, upon decision of the Board, summarized lists of items being safeguarded by the Agency may be published and if all States directly concerned agree, additional information may be published.

Under Part B. Principles of Implementation there appear two qualifications, one related to the pursuit of produced fissionable material and the other related to factors to be considered by the Board when considering the content of Agency safeguards agreements with the State.

> **"16. In the light of Article XII.A.5 of the Statute, it is desirable that safeguards agreements should provide for the continuation of safeguards, subject to the provisions of this document, with respect to produced special fissionable material and to any materials substituted therefor."**

And where the Agency shall require only the minimum amount of information and data consistent with carrying out its responsibility under this section.

In general, these revisions address the preoccupation of some of the States whose nuclear industries were experiencing rapid growth that international safeguards would prove to be a serious economic burden and could possibly seriously jeopardize the competitive position of their industries, as they began to compete for international markets with the United States. As can be seen from the paragraphs which have been

reproduced in Annex E when compared with Information Circular/26 there now appear specific Agency obligations to minimize the impact of safeguards on a State's economic or technological development, the implementation of safeguards should be consistent with prudent management practices, the Agency may not oppose or delay construction of principal nuclear facilities, and the matter of protection of commercial and industrial secrets as well as the protection of any data obtained in the course of the implementation of Agency safeguards have become formalized. The latter point has been noted by many of the Agency's critics as a principal source of the inability of any outside group or State to properly evaluate the effectiveness of Agency safeguards. It is interesting to note, however, that at least in Paragraph 14A a provision is included for making available specific information relating to such implementation in a State to the Board of Governors; and a provision which does not appear in Paragraph 41 of Information Circular/26.

Paragraph 16 of INFCIRC/66 does acknowledge the desirability of providing for the continuation of safeguards on special fissionable materials produced in a facility to which Agency safeguards have been applied or to any material substituted therefore. It can only be observed that the provisions of Paragraph 17 of the Revised Agency Safeguard System represents a considerable departure from the ".. .access at all times to all places and data.. ." of Article XII, A-6 of the Statute.

A comparison of the sections on Design Review in INFCIRC/22 and INFCIRC/66/Rev. 2 reflects, as has been noted, the concern of the States about the possible disclosure of industrial secrets and the need to minimize the impact of the Agency's activities in the exercise of this function. It is important, when considering the effectiveness of Agency safeguards, to keep in mind that no nuclear facility presently under international safeguards inspectio$_n$ included as one of the initial

design requirements of the facility the necessity to optimize safeguards inspection activities. In fact, the safeguards procedures which have been developed have suffered from the fact that even simple provisions which could have been incorporated during the construction of the facility at a relatively modest additional cost were not included. As a result, desirable and sometimes essential modifications could not be made for structural reasons or because the costs would be prohibitively expensive. In this section there is no suggestion that the Agency and the State might at the earliest stages in the design of a nuclear facility review the safeguards requirements in order to ensure that cost effective safeguards might be applied.

One of the earliest applications of Agency safeguards under INFCIRC/26-66 began in 1962 following the completion of negotiations between the IAEA and the AEC for the implementation of safeguards to four U. S. reactors. This was followed by the entry into force on November 1, 1963 of the first Agency trilateral safeguards agreement, an agreement between the United States, Japan and the International Atomic Energy Agency. This Agreement covered any nuclear material, equipment and/or facilities supplied to Japan by the United States. In addition, the Agreement also included the important provision that Agency safeguards would apply to any fissionable material produced in the Japanese facilities even if this material should be returned to the United States for processing unless the United States substituted an equivalent quantity of like material in Japan. This latter feature permitted a supplier country such as the United States, the United Kingdom or the Soviet Union to avoid IAEA inspection of third party fissionable material if the principal of substitution was employed. By the end of 1965 three additional trilateral agreements were in effect, two between the IAEA, Japan, and Canada and the United Kingdom respectively and the remaining between the IAEA, Denmark and the United Kingdom. In the ten succeeding years agreements have been completed

which permit safeguards to be applied in twenty States, under eleven project agreements, twenty-one safeguards transfer agreements, and eight unilateral submission agreements. During 1975 the Agency carried out 299 inspections under these agreements. A list of the agreements providing for safeguards other than those in connection with NPT approved by the Board of Governors as of 31 December 1975 is shown in Annex F.

In 1975 the United States had 30 Agreements for Cooperation in the Civil Uses of Atomic Energy. Of these, 20 were for cooperation in nuclear research and power, 2 involved only nuclear power stations and 8 agreements were for research only. In addition, the United States had bilateral agreements for cooperation with EURATOM and with the IAEA. A list of our Bilateral agreements for cooperation is given in Annex G.

The safeguards provisions of many of these agreements have been suspended and in favor of United States-IAEA Trilateral Safeguards Agreements for the application of safeguards to U. S. supplied material. Annex H contains a list of these U. S.-IAEA Trilateral Safeguards Agreements. A number of these Agreements have been suspended in turn, as a result of negotiations between these countries and the IAEA in fulfillment of the safeguards obligations undertaken in the Non-Proliferation Treaty.

D. NPT OR FULL FUEL CYCLE SAFEGUARDS.

The Treaty on the Non-Proliferation of Nuclear Weapons. On July 1, 1968 the Treaty on the Non-Proliferation of Nuclear Weapons (7, 12, op.cit.) was opened for signature and the Treaty entered into force on March 5, 1970. These events represented the culmination of a major initiative on the part of the United States, the United Kingdom, and the Soviet Union supported by a number of the major non-nuclear industrialized States to limit the further spread of nuclear weapons. In the negotiations on the draft of the NPT, the possibility of including a safeguards article was a subject of extended discussion. With the resolution of the issue in favor of incorporating such an article, the debate turned to the means and methods to be used. The Federal Republic of Germany, in particular, took the position that the formulation of the safeguards principles as expressed in INFCIRC/66 would have to be replaced by a less intrusive and intensive safeguards system which would be applied to all fissionable material in the State, i.e., full fuel cycle safeguard. This new safeguards concept which was included in the preambulatory paragraph to the NPT stated that :

> "Expressing their support for research, development and other efforts to further the application, within the framework of the International Atomic Energy Agency Safeguards System, of the principle of safeguarding effectively the flow of source and special fissionable materials by use of instruments and other techniques at certain strategic points."

The emphasis was on the flow of material at certain strategic points. The safeguarding of facilities had disappeared. The political undertakings designed to halt the spread of nuclear weapons were embodied in Articles I and 11 of the Treaty which provided that both the nuclear weapon States and the non-nuclear weapon States would not transfer or receive whatsoever nuclear weapons or any other nuclear explosive devices. The verification provisions of these

obligations were enumerated in Article III, the Safeguards Article. Article 111 provides that:

> "1. Each non-nuclear-weapon State Party to the Treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency in accordance with the Statute of the International Atomic Energy Agency and the Agency's safeguards system, for the exclusive purpose of verification of the fulfillment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices. Procedures for the safeguards required by this article shall be followed with respect to source or special fissionable material whether it is being produced, processed or used in any principal nuclear facility or is outside any such facility. The safeguards required by this article shall be applied on all source or special fissionable material in all peaceful nuclear activities within the territory of such State, under its jurisdiction, or carried out under its control anywhere.
>
> "2. Each State Party to the Treaty undertakes not to provide: (a) source or special fissionable material, or (b) equipment or material especially designed or prepared for the processing, use or production of special fissionable material, to any non-nuclear-weapon State for peaceful purposes, unless the source or special fissionable material shall be subject to the safeguards required by this article.

"3. The safeguards required by this article shall be implemented in a manner designed to comply with article IV of this Treaty, and to avoid hampering the economic or technological development of the Parties or international cooperation in the field of peaceful nuclear activities, including the international exchange of nuclear material and equipment for the processing, use or production of nuclear material for peaceful purposes in accordance with the provisions of this article and the principle of safeguarding set forth in the Preamble of the Treaty.

"4. Non-nuclear-weapon States Party to the Treaty shall conclude agreements with the International Atomic Energy Agency to meet the requirements of this article either individually or together with other States in accordance with the Statute of the International Atomic Energy Agency. Negotiation of such agreements shall commence within 180 days from the original entry into force of the Treaty. For States depositing their instruments of ratification or accession after the 180 day period, negotiation of such agreements shall commence not later than the date of such deposit. Such agreements shall enter into force not later than eighteen months after the date of initiation of negotiations."

The significant features of Article III-2 are that (1) the IAEA is assigned the responsibility for implementing NPT safeguards as set forth in agreements to be negotiated between the States and the International Atomic Energy in accordance with the Statute of the Agency and the Agency's Safeguards System, (2) the exclusive purpose of the verification is the fulfillment of the States Treaty obligations with a view to preventing the diversion of "nuclear energy from peaceful uses to nuclear

weapon or other nuclear explosive devices" - a significant departure from the initial objective in the IAEA Statute to ensure that atomic energy "is not used in such a way as to further any military purpose," and, (3) of great importance, the provision that safeguards would be required on all source or special fissionable material in all peaceful nuclear activities within the territory of the State, i.e., full fuel cycle safeguards, under its jurisdiction or under its control anywhere. This last provision marks a major advance over the facility specific safeguards system which the Agency had developed under INFCIR 66/Rev. 2.

Information Circular/153. In order to adapt the IAEA's Facility Safeguards System to the new requirements for NPT safeguard on all the fissionable material within a State, the Board of Governors of the IAEA established a committee shortly after the NPT came into force to advise it on the agreements which would be required between the Agency and the NPT Nations. This Safeguards Committee began negotiations in June of 1970. Delegates from 48 Member States of the IAEA participated under the chairmanship of the present Secretary General of the United Nations, Dr. Kurt Waldhein and Prof. Bruno Straub from Hungary. By March of 1971 the negotiations had been completed and in May of 1971 the Agency issued Information Circular/153 (10, op.cit.) entitled "THE STRUCTURE AND CONTENT OF AGREEMENTS BETWEEN THE AGENCY AND STATES REQUIRED IN CONNECTION WITH THE TREATY ON THE NON-PROLIFERATION OF NUCLEAR WEAPONS". The full text of INFCIRC/153 also has been reprinted as Appendix 4 in 'NUCLEAR WEAPONS PROLIFERATION AND THE INTERNATIONAL ATOMIC ENERGY AGENCY", (1., Op.cite)

Nine months after INFCIRC/153 was issued, a "model agreement had been drafted which embodied the principles and safeguards procedures detailed in this Circular especially designed for safeguarding the full nuclear fuel cycle. It is interesting to note, however, that in 1968 the first country to take the step of unilaterally submitting

all of its nuclear activity to the IAEA was Mexico. This action was undertaken in fulfillment of its obligation under Article XIII of the "Treaty for the Prohibition of Nuclear Weapons in Latin America" (THE TLATELOLCO Treaty), (23) which entered into force April 22, 1968. At the end of 1975 the Agency had safeguards agreements in force with 64 states of which 44 were with states party to the NPT (24).

Some of the important provisions of INFCIRC/153 are summarized below and reproduced in Annex 1. As required by the NPT the basic undertaking of INFCIRC/153 (Paragraph 1) requires states party to the Treaty to accept safeguards on all source or special fissionable material in all peaceful nuclear activities within its territory for the exclusive purpose of verifying that this material has not been diverted to nuclear weapons or other nuclear explosive devices. Thus the State is obligated to accept full fuel cycle safeguards, the emphasis is on the diversion of material and the concern is with the use of such material for any nuclear explosive device even if its stated application is for peaceful uses only, i.e., Peaceful Nuclear Explosive (PNE).

Under the Section on Implementation of Safeguards, Paragraphs 4, 5 and 6, the document repeats the provision included in INFCIRC/66 Rev. 2 concerning the protection of commercial interests and industrial secrets and in Paragraph 5 repeats the prohibition that the Agency shall not publish or communicate to any State, organization or person any information obtained by it in connection with the implementation of the Agreement.

Paragraph 6 was drafted in response to the preambulatory paragraph to the NPT which, as has been noted above, introduced the concepts of safeguarding the flow of materials at certain strategic points. The need for cost effective safeguards is stressed and the Agency is enjoined to take full advantage of all technological developments in the field of safeguards. Finally, this paragraph directs that the Agency's safeguards procedures should be concentrated on those stages in the fuel cycle where

nuclear material suitable for weapons purposes is available.

Paragraph 7 is of particular significance and described the establishment of a national system of accounting for the control of nuclear materials. It is this national system that provides the nuclear material accountancy' data and the many reports on which the INFCIRC/153 safeguards system depends. This paragraph also contains the crucial right of Agency inspectors to make independent measurements and observations in the course of verifying that there has been no diversion of nuclear materials from peaceful uses to nuclear weapons or other nuclear explosive devices.

Paragraph 8 is concerned with the provision of design information to the Agency. In order to further protect the proprietary rights of the nuclear facilities the Agency is directed, at the request of the State to examine the design information on the premises of the State and such information need not be physically transmitted to the Agency as long as it is available for examination on the premises of the State.

In Part 2 of INFCIRC/153 the objectives of safeguards are defined in paragraphs 28, 29 and 30. These important paragraphs state that: (1) the objective is the timely detection of significant quantities of nuclear material to the manufacture of nuclear weapons or for purposes unknown and the deterrence of such diversion by the risk of early detection, (2) material accountancy is the safeguards measure of fundamental importance with containment and surveillance as important complementary measures and, (3) the technical conclusion of the Agency's verification activities shall be a statement in respect of each material balance area of the amount of material un-accounted for over a specific period, giving the limits of accuracy of the amounts stated.

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Compared with INFCIRC/66/Rev.2 the Section on Design Information in INFCIRC/153, Paragraphs 42 through 46, represents a considerable elaboration.

Paragraph 43 specifies that Design Information should be made available to the Agency primarily to assist the Agency to monitor the flow of nuclear material, those features relating to material accountancy, containment and surveillance, and those features which will assist in establishing material balance areas, the measurement of flow, and the procedures for physical inventory taking.

For the first time in Paragraph 46 the purpose of examination of Design Information is specified in great detail . For example: to determine material balance areas (MBAs), to establishing timing and procedures for taking physical inventories, to establish research and reports requirements. Of particular interest is the provision that special material balance areas may be established around a process step involving commercially sensitive information, such as the centrifuge cascade of an uranium isotope separation plant. In such an arrangement Agency inspectors would not have access to the cascade area.

The responsibilities of the national systems of accounting and control of nuclear material with respect to the maintenance of records and the submission of reports are elaborated in the sections on Record Systems, Paragraphs 51-58, and the Reports Systems, Paragraphs 59-69. It is clear that NPT or full fuel cycle safeguards is critically dependent on the effective operation of national systems of the States.

The purposes of the three different types of safeguards inspections, ad hoc, routine, and special, are detailed in Paragraphs 71, 72 and 73. Routine inspections are, of course, the most common and Paragraph 72 provides that these inspections are to be made in order to (1) verify the consistency between records and reports, (2) verify the

location, identity, quantity and composition of all nuclear material subject to safeguards, and (3) verify the possible causes of material unaccounted for, etc.

In a significant change related to access for inspections, Paragraph 76 C and D provide for inspectors to have access only to the strategic points specified in the subsidiary arrangements and the State may conclude that unusual circumstances require extended limitation on access by the Agency. In this latter event the State and Agency shall make arrangements which will enable the Agency to fully discharge its safeguards responsibilities.

Finally, and of major importance are the Paragraphs 78 through 81, which are concerned with the frequency and intensity of routine inspections. The emphasis in these paragraphs is on reducing to a minimum the number, intensity, duration and timing of routine inspections consistent with effective implementation of safeguards, cost effectiveness, and optimum use of inspection resources. Formulae are developed for the maximum routine inspection effect (MRIE). For example, the inspection effort for reactors is limited to one sixth of a man-year for each such facility in the State. Facilities handling plutonium or uranium enriched to more than 5% shall be allowed 30 /E man-days where, E is the inventory or throughput, whichever is greater, expressed in effective kilograms. All other facilities are allowed a maximum of 1/3 + 0.4E man-days where E is again the inventory or throughput in effective kilograms.

The Agency is required to duly consider in its safeguards the farm of the material, the effectiveness of the State's accounting and control system and the characteristics of the State’s nuclear fuel cycle.

It was the intent of the Delegations of the Member States that engaged in the negotiations which preceded the drafting of INFCIRC/153 that NPT safeguards would reflect the concepts of safeguarding the flow of nuclear materials at certain strategic points that appeared in the preamble to the NPT. Facilities themselves were no longer subject to safeguards as they had been under INFCIRC/66/Rev.2. The emphasis now was on limited access only to strategic points, the definition of material balance areas, material accountancy and specific formulas for determining the maximum routine inspection effort for any facility as a function of the annual throughput of nuclear material. These departures from the original provisions in the Statute of "access at all times to all places" have been compensated, at least in part by the new requirements for national systems of accounting and control of nuclear material and the redundancy that is inherent in the safeguarding of a State's full nuclear fuel cycle. These new functions are of immense value. One cannot help but recall, however, the fact that the United States and the Canadian Delegation supported by the Soviet Union, fought a loosing rear-guard action during the negotiations in the Safeguards Committee against those delegations which were determined that NPT Safeguards would be held to a minimum, would be as nonintrusive as possible, and could not possibly provide a competitive advantage to those which might not be subject to safeguards because they were either not parties to the NPT or were nuclear weapon States. There seems little question that in the minds of some of the delegations the principal deterrent in the Non-Proliferation Treaty was political in nature and the safeguards provision was secondary.

The critics of safeguards maintain that, in principle, no safeguards system can be perfect yet perfection is what must be assured. Many difficult problems are cited. Among them is the fact that in practice, the cumulative analytical errors in the measurements of the flow of nuclear material in a State's fuel cycle or even in a

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large nuclear plant may be many times the amount of fissionable material required to make an explosive device. Significant quantities are defined in terms of these amounts. Recently, the problem of ''critical time" has received close attention (27). It is argued that now the time required to make an explosive device is so short that safeguards are irrelevant. There is insufficient time to react or respond to a detected diversion. However, in spite of the many limitations which have been so carefully built into INFCIRC/153, it is the opinion of knowledgeable observers that a technically sound and effective Safeguards System can be designed which will meet the NPT objective of "timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities."

Given the constraints, the development of an effective safeguards system becomes primarily a problem of manpower, money, and technological improvements. Some of the results of the present technical analysis of this problem and the proposed technical solutions are presented in the following section, IAEA Safeguards Technical Manual and Safeguards Implementation Procedures.

E. IAEA SAFEGUARDS TECHNICAL MANUAL AND SAFEGUARDS IMPLEMENTATION PROCEDURES

The Safeguards Technical Manual (STM). With the request of the Board of Governors that the Director General use INFCIRC/153 as the basis of negotiating NPT safeguards agreements between the Agency and the non-nuclear weapon States party to Treaty on the Non-Proliferation of Nuclear Weapons, the Staff of the Department of Safeguards and Inspections assisted by experts from the Member States began preparation of a Safeguards Technical Manual which would form the basis of the procedures and techniques used in the Agency's Safeguards System. Two sections of the STM have been completed and issued as technical documents by the International Atomic Energy Agency, INTRODUCTION, PART A-SAFEGUARDS OBJECTIVES, CRITERIA, AND REQUIREMENTS, (4.op.cit.) and, PART E-METHODS AND TECHNIQUES, (28). An outline of the Safeguards Technical Manual is included as Annex 1. The remaining sections, PART B, NUCLEAR ACTIVITY AND FACILITY, PART C, INSPECTIONS, PART D, EVALUATION OF THE INFORMATION, AND PART F, STATISTICAL CONCEPTS AND TECHNIQUES, should be available for distribution in early 1977.

The Introduction to Part A is a concise statement of the Agency's understanding of its responsibilities, the identity of the State as the potential diverter and the necessarily adversary nature of Agency safeguards. The first five paragraphs are reproduced below:

"INTRODUCTION

"Nuclear and non-nuclear material, services, facilities, equipment and information which are to be used for legally defined purposes may be deliberately diverted from these purposes. Potential diverters are facility operators, individuals or groups of individuals and States.

The actions aimed at the detection and deterrence of this diversion are known as safeguards. The IAEA is authorized by its Statute to accept the responsibility of establishing and administering safeguards subsequent to a 'safeguards agreement' with a State or States.

"All safeguards agreements are built on the basis of an undertaking by the State. Before the Treaty on the Non-Proliferation of Nuclear Weapons came into force this undertaking had always been that 'special fissionable and other materials, services, equipment, facilities and information' shall not be 'used in such a way as to further any military purpose'. States party to the Non-Proliferation Treaty (NPT) undertake not to divert 'nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices' . For the application of safeguards these States also have to conclude with the IAEA agreements where this undertaking is incorporated by reference.

"IAEA safeguards are aimed at the timely detection of diversion by States having undertaken to accept safeguards in accordance with an agreement between the IAEA and the State and at the deterrence of such diversion by the risk of early detection by the IAEA. NPT safeguards agreements specify the procedures to be applied for safeguarding nuclear material.

"The IAEA Safeguards Technical Manual describes principles, procedures and techniques for safeguarding nuclear material. Tile IAEA has to decide in each particular situation whether these principles, procedures and techniques enable it to fulfill the responsibility of safeguarding non-nuclear material, services, facilities, equipment and information.

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> "In the Manual, the principle has been adopted that, under any type of safeguards agreement, the objective of IAEA nuclear material safeguards is the timely detection of diversion of significant quantities of nuclear material. The principle has also been adopted that, unless the IAEA Governing Organs establish other guidelines in this respect, the IAEA assumes that the goal of its safeguards procedures is to detect, if it would be missing in a State in a period of one year, the quantity of nuclear material needed to manufacture a single nuclear explosive device."

To this statement should be added the following excerpt from the Introduction to Chapter 2, DIVERSION OF NUCLEAR MATERIAL:

> "In the context of IAEA safeguards, the State with its corresponding capabilities and resources is considered as the potential divertor and the probability of attempted diversion is considered small but finite. The purpose of diversion is assumed to be the acquisition of nuclear material for uses proscribed by the relevant safeguards agreement."

This Chapter includes a systematic analysis of the diversion strategies which could be used by a State in the acquisition of nuclear material. These diversion strategies could involve:

> "a single facility or a number of facilities cooperating in the diversion and its concealment. Diversion could involve material already in a form suitable for the intended use or in a form requiring further processing before such use. This further processing could be undertaken immediately or the diverted material could be stockpiled for processing and used at a later time. The diverter may attempt to use safeguarded facilities to

process material which has been diverted at another safeguarded facility, or material which either is at the starting point of safeguards or has already undergone some processing and which must be under safeguard but has not been declared by the State. Such an attempt would provide the IAEA with a chance to detect at a facility material which had not previously been in a safeguarded facility or material which had been previously diverted.

"The material might be diverted in either a single removal or repeated removals. Immediate detection by the IAEA can only be possible if it applies strict containment and surveillance measures. Verification of the physical inventory and of the material balance provides for a delayed opportunity for detection of diversion."

The Chapter concludes with a section on the importance of diversion. The observation is made that:

"The importance of the diversion depends on the type and amount of diverted material. Materials, e.g., plutonium and highly enriched uranium, which are of immediate use for nuclear explosive devices represents a greater hazard than does the material which requires a lengthy and complex process to be used for these devices."

Table 11 taken from this Chapter, provides rough estimates of the times required to convert different materials to materials suitable for nuclear explosive devices.

Table II

Importance of Diversion (a)

Required conversion of nuclear material to the form suitable for the manufacture of nuclear explosive devices	Material Form	Approximate range of times required to convert nuclear material to the form suitable for manufacture of nuclear explosive devices
Physical change: or chemical and physical change, but no	Plutonium and highly enriched uranium as metal, oxide or solution	Days to weeks
Chemical and physical change with purification	Irradiated fuel, radioactive solution, cold scrap	Weeks to months
Isotopic, chemical and physical change	Natural and low enriched uranium	Less than one year

a) Based on the approximate times required to convert the material to material suitable to manufacture

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The remaining three Chapters of Part A of the STM, the IAEA Safeguards System, the States System of Accounting for and Control of Nuclear Material, and Guidelines for Application of IAEA Safeguard represent the most concise and definitive statement for both critics and advocates alike of the limitations and capabilities of international safeguards. This document should be carefully read and understood. Chapter 111 concludes with the following statement:

> "The technical conclusion of the IAEA's verification activities shall be 'a statement, in respect of each material balance area, of the amount of material unaccounted for over a specific period, giving the limits of accuracy of the amounts stated'. It is important as a measure of the degree of agreement between the measurements of the operator and those of the IAEA and as a measure of the extent and the accuracy of the IAEA's measurements that the technical conclusion of the IAEA's verification activities includes the operator's MUF (Materials Unaccounted For) adjusted for any differences between the IAEA's and the operator's measurements and an estimate of the combined measurement uncertainties as indicated in Section 5.3.4.
>
> "The IAEA shall inform the State of the results of inspection and the conclusions it has drawn from its verification activities in the State, in particular, by means of statements in respect of each material balance area."

Chapter IV discusses the INFCIRC/153 requirement that the State shall establish and maintain a "State's System of Accounting for and Control of Nuclear Material" (SSAC). The SSAC is essential for the effective implementation of NPT safeguards and provides the following objectives for such a State System:

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> "(a) to contribute to the detection and prevention of unauthorized uses of nuclear material, detect losses of nuclear material, and provide information that could lead to the recovery of missing material;
>
> "(b) to provide the necessary means for the State to fulfill its obligations in the field of accounting for and control of nuclear material under international, contractual or other agreements;
>
> "(c) to assist the management of nuclear facilities or custodians of nuclear material to achieve optimum discharge of the obligations imposed on them by the SSAC: and
>
> "(d) to encourage the efficient, safe and economical use of nuclear material by operators through the use of the control measures prescribed by the SSAC."

Chapter V outlines the "Guidelines for the Application of IAEA Safeguards. This Chapter concludes with a discussion of the problems of timely detection, significant quantities, and detection probability and confidence levels. Guidelines are also provided for the verification and the examination of design information, the verification of the information contained in records and reports, the evaluation of material unaccounted for, and guidelines for taking into account the SSAC's activity,

Because of their relevance to any evaluation of Agency Safeguards effectiveness, the Sections on Significant Quantities (5.1.2) and Detection Probability and Confidence Level (5.1.3) are reproduced in Annex J. Based on the amounts of uranium and plutonium required for fast critical masses and experiments with fast critical assemblies the significant quantities of nuclear material required to manufacture a single nuclear

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explosive device has been taken by the IAEA to be:

(1) 8 kilograms of plutonium for all types of plutonium for which the isotopic concentration of PU-238 does not exceed 80 percent.

(2) 8 kilograms of contained U-233 and U-235 when the combined weight of the U-233 and the U-235 isotopes equal or exceed 20 percent of the total weight and when the U-233 isotopic concentration is the larger of the two isotopes. .

(3) 25 kilograms of contained U-235 when the isotopic concentration of the U-235 is larger than the concentration of U-233.

This section ends with the observation that, given the relatively small amounts of nuclear material required to make an explosive device, the IAEA would be confronted, for those States having a sizable scale of nuclear activity, with the necessity of making a statement on the non-diversion of a very small fraction of the State's inventory of nuclear material. Table III is a summary of the accuracy of material balance and frequency of inventory taking expected by the IAEA.

In the absence of any specific mention in either INFCIRC/66/Rev.2 or INFCIRC/153 of the concepts of degree of certitude of detection (detection probability) or the concepts of degree of certitude of not concluding that a diversion has taken place when it has not (confidence level) the IAEA has concluded that these two concepts are implicit in these documents. On the recommendation of Experts from the Member States, the IAEA has cleared values of 95 percent for both the probability of detection and the confidence level of detection.

In evaluating the performance of the Agency's Safeguards System in the future, it is these objectives, criteria and requirements that should be considered.

Table III

ACCURACY OF MATERIAL BALANCE AND FREQUENCY OF INVENTORY TAKING EXPECTED BY THE IAEA

Type of facility	Operator's accuracy of material balance (% of throughput or inventory) [a]	Operator's frequency of physical inventory taking (number per year)
Uranium isotopic enrichment	± 0.2	4
Uranium fuel fabrication	± 0.3	1 - 4 [b]
Plutonium fuel fabrication	± 0.5	4
Power reactors (uranium)	± 0.2	Upon refuelling
Power reactors (plutonium)	-	Upon refuelling
Irradiated fuel processing (uranium)	± 0.8	4
Irradiated fuel processing (plutonium)	± 1	4
Unirradiated scrap recovery	± 2	1 - 4 [b]
Storage	- [c]	1 - 4 [b]
Research and Development	- [c]	1 - 4 [b]

[a] These accuracies are expressed as one standard deviation and represent the total random and systematic error components of a material balance.

[b] Four for plutonium and high enriched uranium (20% or greater in U-235) and uranium-233; two for low enriched uranium (less than 20% U-235); and one for natural and depleted uranium and thorium.

[c] There are no values available.

Safeguards Implementation Practices (SIP's). In parallel with the preparation of the Safeguards Technical Manual by the Division of Development, the Division of Operations began the preparation of Safeguards Implementations Practices documents (SIP) for each safeguarded facility. In contrast to the publication of the STM, the SIP'S are classified as Safeguards Confidential by the Agency not only because these documents are facility specific and may contain proprietary information which either the facility operators or the State are unwilling to release but also because they contain an Agency analysis of the diversion possibilities and the means the Agency may use to detect such activities.

A model SIP outline has been reproduced as Appendix 8 in "Nuclear Weapons Proliferation and the International Atomic Energy Agency" (1, op.cit.).

The SIP's are divided into two parts, a general part containing aspects which are common to all facilities or groups of facilities in a State or States and a facility part which is specific for each facility containing aspects which are particular to the given facility, Material Balance Area (MBA) or group of MBA's. The facility part draws heavily on the information obtained from the design review of the facility and, of particular significance, contains a detailed discussion of the diversion possibilities, means of concealment and the safeguards approach which might be used to detect such diversion.

Perhaps one of the most important functions of the SIP's is that it formalizes the Agency's analysis of the limitations currently experienced in its safeguarding and verification activities and identifies the improvements that should be made. Section 10 summarizes this situation.

IAEA and International Safeguards-E.

"7.0. Limitations

"The purpose of this important section is to draw attention to those shortcomings in safeguards implementations at the facility which are apparent at the time of preparing the SIP. For some reasons there may be a lack of standardization, inadequate inspection, lack of facility information, etc. This section will indicate where work remains to be done. It will also inform the Inspector General and the Director of the Division of Operations that the work is carried out with these shortcomings by the Regional Section.

"The list of limitations can also be used as a check list and will remind the persons concerned to work toward improved conditions. When the situation changes, a revised SIP will have to be issued."

Both the Safeguard Technical Manual and the Safeguards Implementation Procedures reveal an understanding of the necessarily adversary nature of international safeguards inspection and the resources that might be available to the potential diverter, the State. These documents also reflect a determination on the part of the IAEA to undertake meaningful verification and a determination to use not only the best methods and techniques that are currently available but also to remain in the fore-front of the State of the art. It should be observed that these documents like the descriptions of the Agency's Safeguards System which preceded them will evolve and hopefully improve with experience in the years ahead.

IAEA and International Safeguards-F.

F. THE MANAGEMENT AND ANALYSIS OF SAFEGUARDS DATA.

As has been mentioned in the section of this report on the organization of the IAEA and the Department of Safeguards and Inspections, the importance of the collection, processing and analysis of the rapidly increasing amount of safeguards data required by Information Circular 153 has been a subject of intense concern, particularly in the last two years. Starting in the late 60's, the Agency began with a very small staff the development of an indigenous data base management system for the processing of safeguards data and the preparation of reports. The magnitude of the problem to broaden the base of the Agency's in-house capability led initially to the formation of the Information Treatment Group and, very recently, to the decision to establish a Division for Information Treatment. The United States has actively participated in this effort and has over the last two years provided experts both to advise and to work directly with the Agency on this critical problem.

The requirements for the Agency's information handling system have been summarized in the introduction of a report, by Gmelin, FUNCTIONAL CHARACTERISTICS OF THE IAEA'S SAFEGUARDS INFORMATION HANDLING SYSTEM RELEASE 1, (29) which is quoted below:

> [11]2. INFCIRC/153 contains provisions that Member States, having concluded Safeguards Agreements with the Agency, should provide design information and reports on initial inventories, changes in the inventories and material balances in respect of each nuclear facility and material balance area for all nuclear materials subject to safeguards.

IAEA and International Safeguards-F.

"3. The Agency, on the other hand, should establish and maintain an accountancy system which would provide the data on the location and the movements of all nuclear material subject to safeguards on the basis of the reported information in order to support the Agency's verification activities in the field, to enable the preparation of safeguards statements and to adjust the inspection intensity,

"4. The provisions formulated in document INFCIRC/153 are specific in respect of the details of Agency accountancy by requesting the establishment of *a* modern and transparent accounting system, a system based on the material balance and the inventory change concept. These requirements reflect the recognition that the conventional accountancy systems, based on concepts developed in 1945-1950, would not cope with the information requirements of, for instance, IAEA safeguards necessary to follow the nuclear material used in the peaceful application of nuclear energy."

The necessity to maintain the safeguards confidential nature of the information received from the States and processed by the Data Base Information Handling System has contributed to the very slow development of this System.

The realization that the existing Data Base System would not be able to process the very large increases in Data anticipated as a result of the implementation of the IAEA-EURATOM and Japanese Safeguards Agreements as well as the United States and United Kingdom offers, led in October the selection of a commercially developed Data Base Management System to cope with the IAEA's problems. It is the intent to

supplement the new Data Base System with as many as possible of the programs developed for Release 1. However, important areas directly related to a full scale use of all of the information obtained by the Agency remains to be programmed. For example, information contained in inspector working papers are still processed by hand, the critical area of analysis of the data remains to be programmed as does the receipt and processing of data obtained from the non-destructive analysis measurements made by the inspectors.

The creation of a new Division of Information Treatment and the increases in staff of this group should make a major impact on this problem. The details of the organization of the new Division have not been released, however, one suggestion is a threefold division which would cover operational analysis, systems analysis and data analysis. Such an organization would treat the data produced by the facility itself, the data from the full fuel cycle of a State and the statistical treatment of the data obtained from these sources. In order to meet the six-fold increase in data to be processed which is estimated for the calendar year 1977, the staffing of the new division for 1977 has been approved at 12 professionals and 14 GS positions. For 1978 the recommendation is 13 professionals and 18 GS positions. The heavy emphasis in INFCIRC 153 on Material Accountancy and Measurement of the Flow of Nuclear Materials strongly suggests that the critical needs of this function in the months and years ahead must be met, if the Agency is to fulfill its responsibilities under the NPT.

This formidable task is now being coordinated by an inter-agency U. S. team working directly with the Staff of the IAEA to strengthen the Agency safeguards through U. S. Gifts-in-kind. It should be stressed that this is an area where the other major nuclear supplier states could make significant contributions. Every effort should be made to persuade them to do so.

IAEA and International Safeguards-G.

G. **THE CONFIDENTIALITY OF SAFEGUARDS INFORMATION.**

In Article VII F of the Statute, the Director General and his staff are instructed to:

> "...not disclose any industrial secrets or other confidential information coming to their knowledge by reason of their official duties for the Agency."

As has been noted in the sections quoted above from Part B, Paragraphs 13 and 14 of INFCIRC/66/Rev.2 and Part 1, Paragraph 5 of INFCIRC/153, this instruction has been made much more explicit and has been amplified in a number of details. These instructions initially intended to protect the commercial and industrial secrets of the Member States now presents a serious obstacle in the efforts of these States to ensure their bilateral safeguards responsibilities which have been transferred to the Agency under trilateral agreements are being effectively implemented. It appears that without an amendment to the Statute and major revisions to INFCIRC/66 and 153, the Agency cannot legally disclose specific information obtained during its safeguards inspection or from the reports which have been submitted to it by the Member States.

At the present time, the summary information on the safeguards activities of the Agency made available to the Board of Governors by the Director General is identical to the information included in the section on safeguards of the Annual Report. The safeguards summary from the Agency's 1975 Annual Report is reproduced in Annex K with the exception of Table 9 which is reproduced separately as Annex E.

IAEA and International Safeguards-G.

Although the information in the Annual Report is useful to the Board it does not provide the necessary detail, if the Board is to evaluate the effectiveness of the Agency's Safeguards System.

In an effort to resolve this dilemma the Director General mentioned in his report to the General Conference in September, 1976, his intention to submit periodically to the Board of Governors a Special Safeguards Implementation Report (SSIR). It is the intent of the Director General to present relevant information which would enable the Board to arrive at an opinion with respect to the effectiveness of the Agency's safeguards without disclosing confidential information on specific facility and, if possible, without jeopardizing the flexibility of safeguards implementation. The form and content of this report has been reviewed by the Standing Advisory Group on Safeguards Implementation (SAGSI) at its first meeting in December of 1975 and in subsequent meetings in May and October of 1976. It is generally assumed that a complete evaluation of the Agency's safeguards effort will include both quantitative and qualitative information on the verification achieved. Any more specific assessment of the success of SSIR in meeting the requests of the nuclear exporting Member States for reassurance on the Agency's Safeguards System will have to await the submission of this report to the Board of Governors.

IAEA and International Safeguards-H.

H. **DETERMINATION OF NON-COMPLIANCE AND THE AGENCY'S RESPONSE.**

As in the case of release of Safeguards Confidential information discussed immediately above, the actions which the Agency can take in the face of non-compliance are described in general terms in Article XIIC of the Statute reproduced in Annex A above and in more detail in paragraphs 18 through 22 of INFCIRC/153 which are reproduced in Annex L.

The failure of a State to comply with the provisions of INFCIRC/153 and the Safeguards Agreement between the State and the Agency can obviously cover a wide range of issues. At one end of the spectrum these failures might be trivial. They might include inadequacies in the National System for Accounting and Control, questions related to the content of records and reports, their prompt submission, or at the opposite end of the spectrum, a failure to comply with the basic undertaking of the Non-Proliferation Treaty. In general, these matters would be resolved if possible within DSI or the Secretariat and, if sufficiently serious, would be brought to the attention of the Board who shall "call upon the recipient State or States to remedy forewith any non-compliance which it finds to have occurred." On matters of interpretation and application of the Agreement, Paragraph 22 of INFCIRC 153 provides that the issue be submitted to an arbitral tribunal composed of three arbitrators. If this tribunal is not convened within 30 days either party may requests that the dispute be taken to the President of the International Court of Justice.

In practice, a determination by the Director General that the Agency had not been able to verify that there had not been a diversion of nuclear material would begin in the Department of Safeguards and Inspections with a report from the Chief of a Regional Section to the Inspector General that his inspectors, for example, had been

unable to verify an inventory, encountered unusually large, unexplained losses, or that they had other evidence for. the diversion or the apparent diversion of nuclear material. The inspector prior to the submission of his report would have endeavored, in turn, to resolve the discrepancies with the facility operator or at the level of the National System. Both the Agency and the Board are required to afford the State every reasonable opportunity to provide whatever necessary reassurance is required. There can be no question that initially, the Inspector General and the Director General would be faced with a necessity to evaluate both the quantitative and qualitative information before the Director General's report was forwarded to the Board of Governors. Many technical as well as subjective factors would have to be weighed. These would include the effectiveness of the State system of accounting, previous history, the magnitude of the suspected diversion, through-put of the Facility, the precision and accuracy of the measurements by both the Facility operator and the IAEA, the availability and reliability of the containment and surveillance devices, the magnitude of the inspection effort, the performance of inspectors themselves and, one suspects, questions of a political nature.

IAEA and International Safeguards-I.

1. **THE ROLE OF THE BOARD OF GOVERNORS.**

If the Board of Governors is unable to resolve a question of nondiversion brought to its attention by the Director General, it is instructed by the Statute to report the non-compliance to all members and to the Security Council and the General Assembly of the United Nations. Under the Statute, the Board may also "direct curtailment or suspension of assistance being provided by the Agency or by a member and call for the return of materials and equipment made available to the recipient member or group of members." As a final act, the Agency may suspend the membership of the State or States from the exercise of the privileges and rights of the membership. Up until the present time there has not been, of course, any occasion to exercise or test the interpretation of these powers. If, however, the phrase "or by a member" is interpreted to include the Supplier States, the return of this material and equipment at the "demand" of the Supplier States should considerably strengthen the Agency's position. The immensely more difficult problem of the actual application of sanctions would have to be the responsibility of the individual Member States and more particularly of the Supplier States acting individually or in concert. As has already been noted, the Agency cannot prevent diversion nor does it have the power to recover diverted material. It has no police powers.

In general, the Board of Governors operates by consensus. Votes are rarely taken and a demand for vote is made only when a State feels that its vital interests are at stake. The decision of the Board as well as the action of the General Conference have been unique in the absence of the political discord which has characterized the deliberations of many other international organizations. In spite of this record, it is difficult to predict the actions of the Board of Governors should it be confronted with a report from the Director General that he could not verify in a specific

State that there had been no diversion of nuclear material. Although it should not be the case, the response of the Board to such an announcement might be conditioned by the identity of the State and whether or not it was on the Board. Article XI of the Statute provides that:

> "E. Each member of the Board of Governors shall have one vote. Decisions on the amount of the Agency's budget shall be made by a two-thirds majority of those present and voting, as provided in paragraph H of Article XIV. Decisions on other questions, including the determination of additional questions or categories of questions to be decided by a two-thirds majority, shall be made by a majority of those present and voting. Two-thirds of all members of the Board shall constitute a quorum."

One could imagine circumstances surrounding a Board vote on non-compliance in which, regrettably, a majority might be difficult to obtain.

The present Board of Governors now includes representatives from thirty-four states. It must be assumed that this group would not be completely free from the regional, national, and political rivalries which separate the Member States outside of the Agency. Further, it must be assumed that the Governors would operate on instructions from their governments. In the final analysis any action by the Agency whether it involves assistance to a Developing Country, a safeguards inspection, or action by the Board of Governors on the diversion of nuclear materials is possible only with the sufferance of a majority of the Member States. Should the Board be confronted with a proven case of diversion, one must believe that the Member States, recognizing the threat to all, will instruct their Delegations and their Governors to take promptly those actions which are authorized by the Statute.

J. FACTORS INFLUENCING THE EFFECTIVENESS OF AGENCY SAFEGUARDS.

There are several political and institutional factors which may be expected in the next one to two years to have a marked impact on the effectiveness of the IAEA's ability to carry out its safeguards responsibilities. In general, officials, both inside and outside of the IAEA believe that the Agency's success or failure not only in its safeguards endeavors but in the full range of activities which are authorized in the Statute is dependent on the attitudes of the Member States. In the safeguards area the question of the attitude of the Member States is probably the most crucial factor. In spite of the progress that has been made with respect to the need for effective and credible safeguards, there remains an urgent educational need to enlarge the perceptions of the industrial states as well as the developing states on the dangers which proliferation present to all. Given a cooperative attitude by the Member States, their determination that the International Atomic Energy Agency's safeguards will be effective, and that strong National Systems for Accountancy and Control will be established and maintained, reasonable assurance can be provided that the diversion of nuclear materials to weapons purposes can be detected. Failing this, and confronted with inadequate funding and over-riding concerns for either national sovereignty, or the protection of industrial secrets, the success of the Agency's safeguards activities will be placed in serious doubt.

The most pressing, near term problem of an institutional nature directly affecting the operations of the Agency as a whole and its safeguards efforts, in particular, is the matter of the retirement, or imminent contract renewal of many key management people at the highest levels in the Agency. The Director General is sixty-six years old. If he is to have a successor, the nomination must be submitted to the Board of Governors in June of 1977. Many of the members of the Director General's immediate staff are his contemporaries and are also approaching mandatory retirement. Of

immediate concern is the fact that the contract covering the services of Dr. Rometsch, the Inspector General, must be renegotiated or a replacement recruited by September of 1977. The Agency has recently circulated a request for nominations for the position of Director, Division of Operations, Department of Safeguards and Inspections. As a result of the proposed reorganization of D.S.I., Directors will have to be nominated for the new Division of Operations and the Division of Information. Finally, the Head of the Section for Methods and Techniques, Division of Development is also approaching mandatory retirement and a replacement for this position will be required. The staffing of these positions will have a marked and long range effect on the Agency as well as the performance and morale of the Department of Safeguards and Inspections. It is not a matter in which decisions can be delayed. Agency regulations, as well as the needs of the individuals involved require that the personnel decisions in these areas be made as soon as possible.

The reorganization of the Department of Safeguards Inspections noted above was planned to meet the major increase in safeguards activities resulting from the implementation of the IAEA-EURATOM and Japanese Safeguards Agreements and the application of Agency Safeguards under the United States and United Kingdom offers. This substantial increase in the operational activities of D.S.I. will place new and exacting demands on the Department and on the management of the two Operations Divisions. At the level of the Inspector General there will be an even greater need for strong leadership and effective and imaginative management to meet this challenge.

It is too early to evaluate the impact of the very large increases which the United States Congress has authorized to strengthen and support IAEA safeguards. In fiscal 1975, approximately $200,000 was made available in gifts-in-kind through the Foreign Assistance Act. In fiscal year 1977 a total of approximately

$1,600,000 will be available through the Foreign Assistance Act of 1977 for similar gifts-in-kind. It was the recommendation of President Ford that approximately $5,000,000 should be made available to the IAEA over the next five years. The effective use of this money will require a careful and realistic assessment of the Agency' needs. The United States has established an Interagency Group to coordinate this major effort with members drawn from ERDA, State, ACDA, NRC and

Following a meeting in Vienna in November with IAEA and U. S. Mission staffs, an International Safeguards Project Office (ISPO) under the direction of Dr. H. Kouts was set up and a draft Program Plan for Technical Assistance to IAEA Safeguards (30) prepared.

If the United States does not actively strive to broaden this type of support among all of the Nuclear Supplier States and the Soviet Union, there is danger that the United States will find itself carrying a disproportionately large part of the burden. The report of a German decision to contribute approximately $300,000 in similar support for IAEA is heartening and should be encouraged. There are many areas where all of the supplier states could contribute from the training of inspectors to the use of their most advanced nuclear facilities for the development and testing of the newest safeguards procedures and techniques. Every state under safeguards would benefit. Those states that can contribute to the improvement of safeguards have an obligation to do so.

K. THE IAEA'S ROLE IN PHYSICAL PROTECTION.

As has been noted in the section of this report on the Statute of the IAEA and in the excerpt" from the section on Objectives of INFCIRC/225 (14, op.cit.) reproduced in this report, the IAEA does not have any responsibility for the provision, supervision, control or implementation of a State's physical protection system. The Agency may informally advise a State of its observations and it will provide assistance only when so requested by the State. In its role as an informal advisor and at the urging of some of the Member States, the United States in particular, the Agency has, in recognition of the importance of the problem of physical protection, convened a small panel of experts from the Member States in March of 1972. In connection with the recommendations of this panel of experts the Agency has published a document entitled, "RECOMMENDATIONS FOR THE PHYSICAL PROTECTION OF NUCLEAR MATERIALS", (31), which summarize the views of this panel. These recommendations were reviewed in early 1975 by experts from some of the Member States for the purpose of updating the original publication and reflecting the progress which had been made in the area of physical protection. The work of this panel has been published in a document, THE PHYSICAL PROTECTION OF NUCLEAR MATERIALS, INFCIRC/225, (14, op.cit.). The Agency is well aware that physical protection can make a substantial contribution to the effort of deterring the diversion of nuclear material, but it also recognizes that physical protection of nuclear material is an exclusive responsibility of the State, and in some States, an integral part of the State's National System of Accounting and Control.

At the present time, there does not appear a consensus in the Board of Governors, even among the nuclear supplier states on the subject of physical protection. This lack of consensus reflects deep seated national attitudes, for example the British reluctance to arm its police and other civil forces. Without such a consensus it is

not possible to take more positive steps in this area. Even though it is unlikely that the legal responsibilities of the IAEA in this area will change in the near future, the Agency recognizes the need to bring this problem to the attention of a much larger number of other states. It is considering, at this time, the possibility, of convening a meeting on the subject of physical protection for some time in the early part of 1977. In its advisory capacity, the Agency can act as a center for information of physical protection, it can convene, if requested, scientific meetings and symposia on the subject, although no such request has yet been received by the Agency from any country, and finally it could offer technical assistance in this area if asked.

The United States in concert with the IAEA and several other countries is also pursuing the drafting of an International Convention on Physical Security. This initiative was first proposed in a speech by the U. S. Secretary of State, Dr. Kissinger to the United Nations General Assembly on September 23, 1974. In this address, Dr. Kissinger proposed that:

> "The United States will urge the IAEA to draft an International Convention for enhancing physical security against theft or diversion of nuclear material. Such a convention should set forth specific standards and techniques for protecting material while in use, storage, and transfer."

The following year on September 22, Dr. Kissinger said in his address before the General Assembly that:

> "The United States has intensified its efforts within the IAEA and with other nations to broaden and strengthen international standards and safeguards and has proposed an international convention setting standards to protect the physical security of nuclear material in use, storage or transfer."

IAEA and International Safeguards-K.

A revised draft of an International Convention on Physical Protection is now being reviewed. In spite of the Importance and urgency of the problem, previous experience with international conventions suggests that prompt action in this area may not be forthcoming.

IAEA and International Safeguards-L.

L. THE IAEA REGIONAL NUCLEAR FUEL CYCLE CENTER STUDY.

With the growth and spread of nuclear power throughout the world a number of critical questions have arisen with respect to the storage and reprocessing of spent fuel, the storage of radioactive waste, the fabrication of mixed oxide fuel and the stockpiling of plutonium. These matters and related questions of physical security and safeguarding of such facilities were discussed at the General Conference of the IAEA in 1974, and within the General Assembly of the United Nations where Secretary of State, Dr. Kissinger took the occasion to draw the world's attention to these growing problems. In response to these concerns the IAEA undertook a preliminary study of the economic benefits that might result from regional centers for reprocessing and waste management. The results of this study were published by the Agency in September of 1975 (32) and suggested that the economic benefits were sufficient to justify a further detailed study.

Figure 3 is an organization chart of the present, detailed IAEA study on Regional Nuclear Fuel Cycle Centers (RFCC). The comprehensive nature of this undertaking can be seen from the project elements which include mathematical modeling, fuel reprocessing, waste management, mixed oxide fuel fabrication, fuel storage, transport, and the questions of legal and institutional matters. The first of the many reports to be issued by the IAEA was released in July, 1976, (33) on the Institutional-Legal Framework Aspects of the RFCC Study. An outline of the RFCC's Study Project Summary Report is given in Annex M. Publication of the remaining reports are expected in time for distribution at the Saltzburg Conference in May of 1977. A status report on the IAEA study project was issued in September 1976 (34). The status report is reproduced in Annex N.

Project Elements

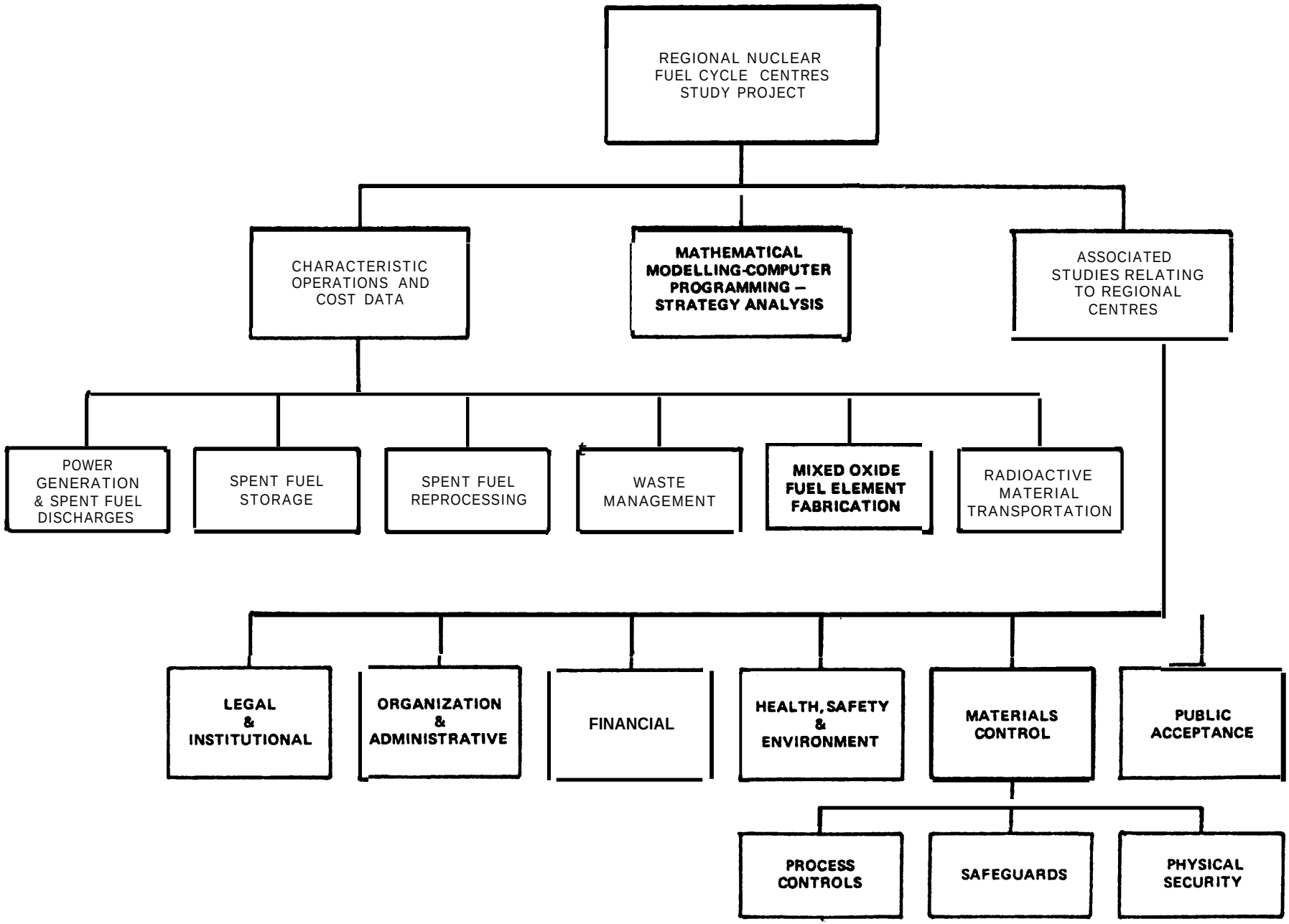

Figure 3

IAEA and International Safeguards-L.

The report on Institutional-Legal Framework Aspects reviews some of the advantages and the disadvantages of the RFCC approach. The advantages include economy of scale, the rational use of technological and financial resources, improved assurances that safeguards and physical protection would be achieved in the interests of all States, and improved management for the safe disposal of high activity radioactive waste. The drawbacks cited include a further spread of sensitive technology, the reduction of freedom for unilateral action by states, concerns about the effects of inter-country frictions on the dependability of fuel supply and the substantial commitment of capital and resources that would be required for individual fuel cycle centers in each of the countries of the region. The report also reviews the organization and experience in the nuclear field of three operating multinational activities, EURODIF and Eurochemic, and URENCO. The main topics covered are legal status and structures, governmental/non-governmental roles, internal administrative structures, commercial/service roles, industrial arrangements, technology (use, control, etc.), basic financial policy considerations, privileges and guarantees, membership, duration, etc., and international agreements.

A more detailed analysis of the multi-national or regional fuel cycle centers have identified the following: potential problems and limitations:

- the interpretation of Article IV of the NPT by signators of the Treaty, i.e., “the right of all Parties to the Treaty to participate in the, fullest possible exchange of equipment, materially and scientific and technological information for the peaceful uses of nuclear energy.”

IAEA and International Safeguards-L.

- **the RFCC's would not necessarily stop participating States from building small indigenous reprocessing plants**

- **the possibility of abrogation and take over of the RFCC**

- **the large RFCC's would unavoidably encounter problems of precision and accuracy of measurements of material unaccounted for associated with large throughput and material flow,**

the RFCC might/would speed rather than contain the spread the transfer of sensitive technology.

- **the plutonium obtained from a RFCC and used in mixed oxide fuels (MOX) could still be easily separated prior to irradiation of the fuel in a reactor and diverted.**

In addition to the economies of scale. improved safeguards and enhanced physical protection noted above, RFCC's could have tile following advantages:

- **the reduction of regional rivalries and the incentive for small, inefficient national reprocessing plants.**

- **the reduction of incentives for premature reprocessing of spent fuel.**

- **the reduction of safeguards costs.**

- **the limitation of the spread of sensitive technology**

IAEA and International Safeguards-L.

- an enhanced role for the IAEA
- the early establishment of regional spent fuel storage sites to reduce requirements for early reprocessing.

The Director General in his statement to the General Conference in September said "'The Secretariat's study tends to indicate that such projects would be advantageous from an economic, safety, physical security, and safeguards point of view*'. There are many critics who would take exception to this statement. The question of the economics of reprocessing is still a subject of intense debate. There does, however, appear to be an important role for the IAEA in the supervising the storage of spent fuel and in the management of separated plutonium, two possible functions for a RFCC. It is possible that Article XII(A5) of the Statute which provides for the deposit with the Agency of any excess of any special fissionable material recovered or produced as a product over what is needed for immediate use may provide the legal basis for a solution to dangerous situations.

APPENDIX IX-D

EURATOM AND REGIONAL SAFEGUARDS

by

Stieff Research and Development Co., Inc.

EURATOM AND REGIONAL SAFEGUARDS

A. The Treaty of Rome.

The Treaty of Rome, establishing the European Atomic Energy Community, was signed on the 25th of March, 1957 by Representatives of the Governments of Belgium, Germany, France, Italy, Luxembourg, and the Netherlands. Since that time, the European Community has been enlarged by the accession of three new Member States; the United Kingdom, Denmark, and Ireland. With the signing of the Treaty, and the simultaneous signing of the Treaty establishing the European Economic Community, the first multi-national safeguards system was created. This Treaty delegated to the Community and to its executive body the Commission, the responsibility of controlling the nuclear materials within their territories. With this act, the Member States relinquished real and significant aspects of their power and national sovereignty to the Community. The history of EURATOM has been summarized by Warren H. Donnelly, (35) in a report prepared for the Subcommittee On National Security Policy and Scientific Developments of the Committee on Foreign Affairs, U. S. House of Representatives.

The safeguard objectives, rights, and responsibilities of EURATOM are contained in Chapter 8, Safeguards, Articles 77 through 85 of the Treaty, (36). These articles are reproduced in full in Annex O.

> "in accordance with the provisions of this Chapter that the Commission shall satisfy itself that, in the territories of the Member States (a) ores, source materials and special fissile materials are not diverted from their intended use as declared by the users;"

The provision of this Article are of particular interest for two reasons. First, safeguards in the EURATOM systems begins with the ore as contrasted with IAEA safeguards which under Information Circular/153, para. 33 states:

> **"safeguards shall not apply thereunder to materials** in mining or ore processing activities."

Second, the phrase,

> "as declared by the users",

is in marked contrast to the undertaking in the NPT or in INFCIRC/153, that "such material is not diverted to nuclear weapons or other nuclear explosive devices," or the Statute's phrase not "to further any military purpose." This formulation apparently reflects the French insistence that the EURATOM Treaty must not restrict her national atomic program nor her right to produce and use atomic weapons for national security.

The design review provisions of the IAEA Safeguards Systems find their equivalent in Article 78 which provides that "Anyone setting up or operating an installation for the production, separation or other use of source material or special fissile material or for the processing or radiating nuclear fuel shall declare to the Commission the basic technical characteristics of the installation to the extent that knowledge of these characteristics is necessary for the attainment of the objective set out in Article 77." Thus, although the EURATOM Treaty does not prevent a State from constructing facilities to manufacture nuclear weapons it does prevent facilities whose declared functions are in the peaceful uses of atomic energy from being used for weapons purposes. This aspect of the Treaty has been strengthened by the ratification of the NPT by the EURATOM countries with the exception of France.

EURATOM and Regional Safeguards

The records provisions of the EURATOM Treaty are covered in Article 79. Article 80 contains a provision, analoguous to Article X11(5) of the Statute that specifies "the Commission may require that any excess special fissile material recovered or obtained as bv-products and not actually being used or ready for use shall be deposited with the Agency or in other stores which are or can be supervised by the Commission". The rights and privileges of the Commission to send inspectors to the territories of the member states are covered in Article 81, and this Article contains the important right of the inspectors who "shall at all times have access to all places and data and all persons who by reason of their occupation deal with materials, equipment or installation subject to the safeguards provided for in this chapter."

These very broad inspection rights are in fact exercised by the EURATOM inspectors. For example, it is reported that in recent EURATOM inspections of the URENCO Centrifuge Enrichment Plant in Almelo, the Netherlands, the centrifuge cascade itself has been included as part of inspection. Under the procedures which the IAEA expects to use for enrichment plant safeguards, its inspectors would not have access to the cascade area because of the commercial sensitivity and weapons potential of the technology.

The actions which the Commission may take in the event of non-compliance with the provisions of the Treaty, are outlined in Articles 82 and 83. These actions include in Article 83(1) "(c) the placing of the undertaking for a period not exceeding four months under the administration of a person or board appointed by **common accord of the commission of the state having jurisdiction over the** undertaking; and (d) total or partial withdrawal of source materials for special fissile materials." Under Article 83(4) of the Treaty "the member states shall insure that sanctions are enforced and where necessary that the infringements are remedied by those committing them.

EURATOM and Regional Safeguards-B.

B. REGULATION NO. 7 AND NO. 8

Regulation No. 7 which outlines the procedures for completing the declarations laid down in Article 78 of the Treaty was approved by the Commission in Brussels on the 18th of February, 1959. The Regulation and its Annex specify the Design Information which should be provided for the Commission in what is the equivalent of the IAEA Safeguards System's design review questionnaire. It requires a brief description and general plan of the installation, a description of the technical processes employed, a description of the methods used in the installation for measuring and checking the quantity and quality of materials which are subject to safeguards and information on the composition and nature of the nuclear production of the nuclear materials used or produced in the facility as well as its annual capacity.

Regulation No. 8 approved on the 12th of March 1959 defines the nature and extent of the requirements referred to in Article 79 of the Treaty. This Regulation specified the records and reports that the Commission would require in order to determine the quantity and nature of the materials subject to safeguards and in actual existence in the community, the place where they are located and the transfers in which they are involved. This Regulation is analogous to the Sections on Records and Reports of the IAEA Safeguards System. The facility operator has a relatively large degree of freedom in the manner the records are kept. The records, however, must contain all of the necessary data which are or may be required for the material accountancy of all source or special fissionable material and the operator must be able to substantiate the reports which are made. The records must be accessible to the inspector. Each facility must report separately for each material and for each "stage of production" such as the concentration of ores, chemical reprocessing of concentrates, production of hexafluoride

EURATOM **and Regional Safeguards-B.**

enrichment, spent fuel reprocessing, etc. In general, reports are required monthly and indicate all inventory changes of the facility and include an inventory statement of all of **the materials present in the last day of the month.**

EURATOM and Regional Safeguards-C.

c. THE EURATOM SAFEGUARD SYSTEM

In 1960 approximately one hundred nuclear facilities within the Community were covered by EURATOM Safeguards. This number had grown to approximately four hundred by 1975. Table IV and Table V are taken from the review article by Schleicher, (37) which describes the Euratom Safeguards System and which summarizes both the number of installations and the amount of nuclear material under EURATOM control.

TABLE IV

TOTAL NUMBER OF INSTALLATIONS IN CATEGORIES

IN JANUARY 1975

Category	Number Safeguarded
Research laboratories	87
Mines	28
Mineral concentration	8
Mineral refining	6
Enriched uranium production	7
Fuel preparation	8
Fuel production	27
Reprocessing	13
Research reactors	72
Critical assemblies)	
Subcritical assemblies)	47
Power reactors	65
Stores	20

EURATOM and Regional Safeguards-C.

TABLE

AMOUNTS OF NUCLEAR **MATERIAL UNDER EURATOM CONTROL**

IN JANUARY 1975

Type	Quantity (Kg element)
Plutonium	14 844
Enriched uranium	3 529 985
Natural uranium	32 744 760
Depleted uranium	6 467 924
Thorium	3 038 844

The rate of growth of the EURATOM system is expected to increase with twenty-five new nuclear power stations under construction, the addition of major new facilities for uranium enrichment planned and started, and, with the implementation of United Reprocessors, the European reprocessing cartel, well under way.

At the present time the Safeguards Directorate of the Commission, which is located Luxembourg, has a staff of approximately 110 people. The staff, as is the custom with all European Community Organizations, is drawn from all nine Member States. Because of the confidential nature of safeguards, each staff member is cleared for access to secret material. The Directorate is subdivided into three divisions, each Division being responsible for the inspection of certain specific types of facilities. A special service group provides computer support and is responsible for processing the monthly material accountancy reports. Of the 60 inspectors on the EURATOM staff

approximately 50 participate routinely in inspections. Roughly one-third are university graduates. It is the EURATOM practice that the inspectors specialize in certain types of installation and are responsible for these installations wherever they may be found within the European community. The inspector proposes the inspection methods to be used for specific facilities, examines the records and reports of the facility, reviews the differences between the operators declarations and his findings and makes the first recommendation on the admissibility of losses and wastes reported by the facility operator. The final decision on this latter matter is made at the level of the Directorate.

The EURATOM data processing system currently handles approximately 20,000 entry lines each month from the 400 installations under safeguards and has recently been described by Schmitt and Kschwandt (38). The accounting system is based on batch processing in the computer sense rather than the material balance area concept used by the IAEA. This basic difference has required major reprogramming efforts on the part of the EURATOM staff in order to meet the requirements of INFCIRC/153. The first test-runs of the revised monthly reports using magnetic tapes have been processed in Vienna without major difficulties.

The preliminary budget for EURATOM safeguards for the year 1977 is estimated at approximately 732,000 units of account(u.a.) or, approximately $800,000. if the conversion factor of 1.1 is used for the u.a. A copy of the preliminary draft of the General Budget for expenditures relating to safeguards is reproduced in Annex P.

EURATOM and Regional Safeguards-D.

l'). **IAEA/EURATOM SAFEGUARDS AGREEMENT.**

In fulfillment of their obligation under Article 3 of the Non-Proliferation Treaty the representatives of the seven non-nuclear weapons states of the European Community and, the representatives for the European Atomic Energy Community, and for the International Atomic Energy Agency signed on April 5, 1973 the "TEXT OF AN AGREEMENT BETWEEN THE EUROPEAN ATOMIC ENERGY COMMUNITY AND THE AGENCY IN CONNECTION WITH THE TREATY ON THE NON-PROLIFERATION OF NUCLEAR WEAPONS." This Agreement incorporates the principles and in many instances the phraseology used in drafting INFCIRC/153. There are, however, some significant differences. The most important issues concern the nature of the inspection activities which the IAEA may perform during its verification of EURATOM safeguards and the question of access and inspection effort.

Article 3(b) contains the sentence, "... The Agency's verification shall include, inter alia, independent measurements and observations conducted by the Agency in accordance with the procedures specified in this Agreement."
In the Protocol to the Agreement which is reproduced in Annex A, Article 14, the question of the Agency's activities are described in *more* detail. For example, it is provided in paragraph (a) that

> "the Agency inspections shall be carried out simultaneously with the inspection activities of the Community. Agency inspectors shall be present. during the performance of certain of the Community inspections. [11]

Paragraph (b) provides that

> "whenever the Agency can achieve the purposes of its routine inspections set out in the Agreement, the Agency inspectors shall implement the provisions of Articles 74 and 75 of the Agreement through the observation of the inspection activities of the Community inspectors, provided, however, that:
>
> "(i) With respect to inspection activities of Agency inspectors to be implemented other than through the observation of the inspection activities of the Community inspectors, which can be foreseen, these shall be specified in the Subsidiary Arrangements; and
>
> "(ii) In the course of an inspection, Agency inspectors may carry out inspection activities other than through the observation of the inspection activities of the Community inspectors where they find this to be essential and urgent. If the Agency could not otherwise achieve the purposes of its routine inspections and this was unforeseeable."

The Agency's position with respect to the interpretation of the word "observation" is presented in the introduction Chapter 3, of the IAEA Safeguards Technical Manual (28, op. cit.).

EURATOM and Regional Safeguards-D.

“INTRODUCTION

“3.1 The IAEA safeguards system must **enable the IAEA to** verify that a State has complied with **its undertaking as specified in the relevant safeguards agreement. The safeguards responsibilities and rights of the IAEA can not, therefore, be delegated to the State or to any organization to which the State has delegated the State’s responsibilities. The IAEA system has been conceived to ensure the timely detection of diversion that might be attempted by the wide range of strategies described in Chapter 2. For these reasons the IAEA must verify the completeness, formal correctness and validity of the information (including all records and reports) made available by the State, regardless of the nature or level of the verification activities carried out by the State.**

The important matters at issue between the IAEA and EURATOM concern the interpretation of the word ‘Observation”. In resolving this matter it will be necessary to consider the Agency’s statutory requirements as well as the need to prevent unnecessary duplication of effort, unnecessarily high costs for safeguards, inspections, and the preservation of the EURATOM Safeguards System itself. In this, as in other crucial questions related to Safeguards, the attitudes of the parties involved is of major importance and a solution to the problem can be found if it is the desire of all sides to do so.

E. THE NEW REGULATION

On September 22, 1976 the Commission of the European communities published a new regulation concerning the application of the provisions on EURATOM safeguards (6, op. cit.). The new Regulation has EURATOM Treaty Articles 77, 78, 79 and 81 as its legal basis. It was prepared in accordance with the IAEA EURATOM Safeguards Agreement concluded on the 5th of April 1973. The Commission used this occasion to define new procedures to be used in accordance with the provisions of Chapter VII of the Treaty of Rome, to make the necessary changes and modifications in EURATOM procedures so that its reports would be compatible with IAEA requirements, and to modify the EURATOM nuclear materials accounting procedures so that they would be in accordance with the requirement of the IAEA.

The first part of the Regulation concerns the declaration and verification of the fundamental technical characteristics of installations for the production, separation or utilization of source or special fissile materials or the reprocessing of irradiated nuclear fuels. The declaration involves notification of the installations programmed. The second part of the Regulation specifies the accounting system for nuclear materials. The system involves accounting and operating records and includes information on the quantities, nature, form and composition of the materials. The third part regulates imports and exports of source and special fissile materials. The fourth part contains specific provisions applicable to ore producers, carriers and intermediaries.

The fifth part, under Article 35, lays down specific provisions applicable in the territories of the nuclear- capon Member States. It is stipulated that the Regulation shall not be applicable to installations or materials allocated to defense by a Member State which is not a party to the Verification Agreement. The Regulation is nevertheless applicable, in a manner to be agreed between Commission and Member State, to installations and materials which are only temporarily or partially assigned to a defense requirements.

Schleicher, (37, op. cit.) in discussing the implementation of the IAEA/EURATOM Safeguards Agreement contrasts what he describes as the flexibility of the EURATOM System with the much more formal character of the IAEA System. Concern is expressed for the additional safeguards burden which will result from the IAEA requirements for verification of physical inventories. The possibility is specifically mentioned of the need to shut-down large nuclear facilities in order to take such inventories and the considerable expenses which such a shut-down would entail. Coupled with this inventory verification problem in Schleicher's view is the additional burden resulting from the requirement by the Agency for relatively large numbers of destructive analyses for uranium and plutonium. These analytical requirements would significantly increase the cost of safeguards. As has been mentioned, the major differences in the accounting and reporting procedures as well as the data analysis methods used by the two safeguards system reflect fundamental differences in safeguards philosophy. Once again these difficult and practical problems can be resolved if both parties are determined to work for a mutually acceptable solution.

The Director General of the IAEA reported in his speech to the General Conference that:

EURATOM and Regional Safeguards-E.

> "At our General Conference in Mexico in 1972, I was pleased to announce that the Board and the Council of Ministers of the European Communities had approved the NPT Agreement between the Agency and EURATOM and the States concerned, I had hoped to be able to inform the General Conference at this session that the Agreement had entered into force, but I am, unfortunately, not yet able to do so. I must draw attention to the fact that even under the most liberal interpretation, the time limit set by NPT for the entry into force of that Agreement will expire early in November this year. I do hope that I shall be able to inform the General Assembly of the United Nations later this year that the ratification of NPT by the countries concerned, which was met with so much gratification in Nay last year, has been consummated by the entry-into-force within the statutory time limit of the IAEA/EURATOM Safeguards Agreement."

At this writing, the statutory time limit has passed and the IAEA/EURATOM Safeguards Agreement is not in force.

APPENDIX IX-E

NUCLEAR SUPPLIERS CONSULTATIONS - 1

by

Ted Greenwood

Suppliers Consultations - 1

Since the dawn of the nuclear age no student of nuclear matters has doubted that any country that learned enough about nuclear technology to operate a nuclear power industry would in the process learn a great deal that is relevant for the design and fabrication of nuclear weapons. With varying levels of success the international community has sought to respond to what has been perceived to be a threat to world peace and security from this overlap between peaceful and military uses of atomic energy. The great successes include the establishment of the international safeguards system of the International Atomic Energy Agency (IAEA), the Treaty for the Prohibition of Nuclear Weapons in Latin America and the Non-Proliferation Treaty (NPT). Within this same tradition have been efforts of nuclear supplier states to act in concert to minimize the likelihood that the diffusion of peaceful nuclear technology will encourage or make easier the spread of nuclear weapons.

The First Suppliers' Agreement

On August 22, 1974, Australia, Denmark, Canada, the Federal Republic of Germany, Finland, the Netherlands, Norway, the Soviet Union, the United Kingdom and the United States filed identical memoranda with the Director General of the International Atomic Energy Agency concerning "procedures in relation to exports of (a) source or special fissionable material, and (b) equipment and material designed or prepared for the processing, use or production of special fissionable material."[1] As stated by all these states, except the Federal Republic of Germany and the Netherlands which had at the time not yet ratified the Non-Proliferation Treaty, these memoranda were intended to coordinate the fulfillment of "commitments under Article III paragraph 2 of the Treaty on the Non-Proliferation of Nuclear Weapons not to provide such items to any non-nuclear-weapon State for peaceful purposes, unless the source or special fissionable material is subject

to safeguards under an agreement with the International Atomic Energy Agency."[2] The documents relating to this agreement were distributed by the IAEA in INFCIRC/209, a copy of which is provided as Appendix A.

The agreed procedures and the so-called Trigger List was the result of several years of negotiation and represented the first major agreement on uniform regulation of nuclear exports by actual and potential nuclear suppliers. It had great significance for several reasons. It was an attempt to enforce strictly and uniformly the obligations of Article III paragraph 2 of the Non-Proliferation Treaty. It was intended to reduce the likelihood that as a result of competition in the sale of nuclear equipment and fuel cycle services, states would be tempted to cut corners on safeguard requirements. In addition, and very important in the light of subsequent events, it established the principle that nuclear supplier nations should consult and agree among themselves on procedures to regulate the international market for nuclear materials and equipment in the interest on non-proliferation. Notably absent from the list of participant actual or potential suppliers as from the list of parties to the NPT were France, India and the People's Republic of China. By 1974, however, French policy had changed to one of respect for the agreed-upon Trigger List and in all other matters related to nuclear exports to act as if she were a party to the NPT.

The 1976 Agreement

Within a year of the delivery of these memoranda a second series of supplier negotiations were underway.[3] This round, convened largely at the initiative of the United States, was a response to the Indian nuclear test of May 1974, mounting evidence that the pricing actions of the Organization of Oil Exporting Countries were stimulating third world and other non-nuclear states to initiate or accelerate their nuclear power programs, and recent contracts or continuing negotiations on the part of France and West Germany for the supply of enrichment *or* reprocessing facilities *to* third world states, The initial participants in these discussions, conducted in London under the veil of official secrecy, were Canada, the Federal Republic of Germany, France, Japan, the Soviet Union, the United Kingdom and the United States.

Two major issues were discussed in the series of meetings leading to a new agreement in late 1976. The first was whether and if so under what conditions technology and equipment for enrichment and reprocessing, the most sensitive parts of the nuclear fuel cycle from a weapons proliferation perspective, should be transferred to non-nuclear states. The United States, with support from several other participants was reported to argue in favor of a prohibition on such transfer and a commitment to reprocessing in multinational facilities. France had already signed contracts to sell a small reprocessing plant to Pakistan and South Korea and West Germany had agreed to sell technology and facilities for the full fuel cycle to Brazil. They successfully resisted the prohibition proposed by others. The second issue was whether transfers should be made to states unwilling to submit all non-military nuclear facilities to IAEA safeguards, or whether total industry safeguards should become a condition on sales.

On January 27, 1976, the seven participants in the negotiations exchanged letters endorsing a uniform code for conducting international nuclear sales. The major provisions of the agreement require that before nuclear materials, equipment or technology are transferred, the recipient state must:

1. pledge not to use the transferred materials, equipment or technology in the manufacture of nuclear explosives;
2. accept, with no provision for termination, international safeguards on all transferred material and facilities employing transferred equipment or technology, including any facility that replicates otherwise employs transferred technology;
3. provide adequate physical security for transferred nuclear facilities and materials to prevent theft and sabotage; and
4. agree not to retransfer the materials, equipment or technology to third countries unless they too accept the constraints on use, replication, security and transfer and unless the original supplier nation concurs in the transactions.

There is of course a problem in trying to impose such constraints on the diffusion of technology. Technical advances made by the recipient country may alter the initial technology to the point where it can be

reasonably claimed to be different technology. Such ambiguities are handled by specifying an arbitrary time period - reported to be twenty years - within which all related technology will be unambiguously considered to be transferred technology and after which differing interpretations may be possible. The basic obligation, however, is not limited in time. A copy of the news release of February 23, 1976 of the U.S. Arms Control and Disarmament Agency discussing these provisions is attached as Appendix B.

Evaluation of the 1976 Agreement

It is important to recognize what this suppliers' agreement does and does not do. It does not ban transfers to non-parties of the NPT or to states that refuse to place all nuclear facilities under IAEA safeguards.* It also does not ban the export of reprocessing and enrichment facilities and equipment. Rather than deny states technology that is relevant to explosives programs, the agreement attempts to replace weakening technological barriers against nuclear proliferation with such institutional and political barriers as safeguards and governmental pledges.

It requires IAEA safeguards be applied to and a no-explosives-use pledge be associated with not only such facilities that are actually exported but also other facilities the recipient may build based on the same technology. This is a significant strengthening of the provisions previously applying to Trigger List equipment. The re-transfer provision not only precludes states acquiring technology with fewer constraints by retransfer but also gives the exporter a veto over what countries may receive retransfers. In this way any countries thought to be particularly high-risk can be prevented from obtaining help via an intermediary. The provisions also explicitly recognize the importance of physical security protection of nuclear materials and facilities and will strengthen the IAEA in its role as advisor on physical security matters to interested states.

Beyond the agreement's provisions themselves, its very existence and the process of negotiation that produced it have some significant implications.

*Ratification of the NPT or acceptance of international safeguards on all nuclear facilities has now been adopted unilaterally by Canada as a condition for the supply of reactors or uranium. Canada has also called on other suppliers to adopt comparable conditions of export.[4]

The most important benefit is perhaps the strengthening of the international norm proscribing the acquisition of nuclear weapons by non-nuclear states. The importance that nuclear supplier states attach to the prevention of proliferation is indicated and symbolized by their agreement on uniform standards despite the rather considerable opportunities and incentives for each state to compete for sales in a rather tight and lucrative export market by demanding less stringent anti-proliferation requirements than other venders. In addition, the process of negotiation and the publicity associated with it, were instrumental in causing the issues of nuclear proliferation and nuclear exports to be raised to the highest political levels within the governments of all participants. Rather considerable pressure could therefore be brought to bear on France and West Germany to adopt a policy more closely in line with other major exporters. While producing only partial (although still quite significant) changes before the major agreement on January 1976 was achieved, subsequent statements by both governments indicate continued movement closer to the American position and away from insistence on the right to export sensitive facilities. Finally, the existence of the supply negotiations made more likely, less difficult and less costly the application of American pressure on South Korea and Pakistan to abandon their plans to build reprocessing plants and increased the political cost for other states that might be contemplating acquiring reprocessing facilities.

On the negative side is the fact that the negotiations have involved only actual and potential nuclear suppliers. Having conducted the negotiations in official secrecy and totally outside the IAEA context, the parties have left themselves open to several criticisms by potential purchasing states. The first is that the suppliers are in violation of their obligations under Article IV Paragraph 2 of the NPT “to facilitate . . . . the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy” and to "cooperate in contributing . . . .to the further development of the application of nuclear energy for peaceful purposes, especially in the territories of non-nuclear-weapon States party to the Treaty, with due consideration for the needs of the developing areas of the world." The second possible criticism is that through the suppliers' agreement a group of industrialized states

have formed a nuclear cartel and conspired to promote the continued dependency on themselves of developing countries that will be prevented from acquiring industrial capability the importance of which for building modern industrial economies is demonstrated by the suppliers' own pursuit of such capability.

If such interpretations gain favor among potential recipients states, the suppliers' agreement could contribute to a weakening of the sense of bargain on which rests the acceptability of the NPT to many non-nuclear states. It could also weaken the American argument in international forums that cartelization is an inappropriate mechanism for organizing commodity markets. In addition, it could become a symbolic issue of contention in the context of North-South negotiations over the distribution of the world's resources, wealth, technological capabilities and power.

Current and Future Issues

As of November 1976, Belgium, Czechoslovakia, East Germany, Italy, the Netherlands, Poland, Sweden and Switzerland are reported to have adopted the suppliers' guidelines and joined the suppliers discussions.[5] This raises the number of participants *to* fifteen and omits only Argentina, India and South Africa of those states potentially able to enter the nuclear equipment or services export market in the foreseeable future. There is still no indication that the IAEA will become involved, even to the extent of serving as a communications medium to other *states* as it did in the case of the 1974 Trigger List agreement. Possible items for future agendas of the suppliers? group include reopening the question of reprocessing and enrichment exports, establishing uniform non-proliferation provisions in Agreements for Cooperation and contracts leading to the supply of enrichment or reprocessing services, and multinational fuel reprocessing *or* spent fuel storage facilities.

Now that France and West Germany seem to have altered their own positions on the issue of sensitive technology exports, this question might be taken up again in the multinational forum. A total ban on the transfer of enrichment and reprocessing technology and equipment, if it were achievable, would be a very significant negotiating accomplishment. Except to the extent that it would further reinforce the norm

proscribing proliferation, however, it might not contribute very much to the objective of preventing non-nuclear states from obtaining the technical capabilities to produce weapons grade materials. Such a capability would be relatively easily acquired by any state with sufficient technical sophistication to sustain a domestic nuclear power industry. The technical demands for building small plutonium production reactors and a fuel reprocessing plant whose only purpose was to recover weapons grade plutonium from low burnup fuel are significantly less stringent than those required to sustain a commercial nuclear industry. Indeed, many third world nuclear states would be capable, completely on their own, of building a small, pilot plant scale, commercial reprocessing plant if one could not be purchased on the international market. Except for operational experience and industrial know-how of those who have actually operated plants, the technology for reprocessing is totally in the public domain. The great danger of a ban on the transfer of technology is that states determined to obtain a reprocessing facility may build one on their own, and then, if they are not parties to the NPT be under no obligation to the international community regarding safeguards or non-weapons-use.

I-f the suppliers decide that providing market incentives is a useful means of discouraging states from seeking their own sensitive fuel cycle facilities, they might take up questions such as the supply of enrichment and reprocessing services. Just as in the case of technology exports, in order to avoid competition among suppliers of services that encourages one state to impose less stringent non-proliferation-related conditions on its customers than another, agreement on uniform standards would be very useful. In addition, to satisfy those states who wish to dispose of spent fuel or who might turn to reprocessing to help manage their nuclear waste, the supplier states could act to create or encourage the creation of one or more spent fuel repositories under national or multinational control. These might be associated with reprocessing facilities or be independent. In the former case, agreement would have to be reached concerning whether or under what conditions recovered plutonium would be returned to the country from which it came.

1. International Atomic Energy Agency, INFCIRC/209, p. 1.

2. ibid.

3. David Binder, "6 Nuclear Lands Meet on Control", The New York Times, (June 18, 1975), p. 1.

4. The Honorable Donald Jamieson, "Canada's Nuclear Export Policy", Text of Statement on Motions Made in House of Commons, Ottawa, 22 December 1976.

5. David Binder, "15 Major Nuclear Nations Will Discuss Ways to Curb Spread of Ability to Make Atomic Arms", The New York Times, (November 9, 1976), p. 7.

APPENDIX A

IAEA INFCIRC/209

Communication Received from Members Regarding the Export of Nuclear Material and of Certain Categories of Equipment and Other Material

INFCIRC/209
'3 September 1974
GENERAL Distr.
Original: ENGLISH and RUSSIAN

International Atomic Energy Agency

INFORMATION CIRCULAR

COMMUNICATIONS RECEIVED FROM MEMBERS REGARDING THE EXPORT OF NUCLEAR MATERIAL AND OF CERTAIN CATEGORIES OF EQUIPMENT AND OTHER MATERIAL

1. On 22 August 1974 the Director General received letters, all dated that day, from the Resident Representatives to the Agency of Australia, Denmark, Canada, Finland, Norway, the Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland and the United States of America, relating to the commitments of these eight Members under Article 111, paragraph 2 of the Treaty on the Non-Proliferation of Nuclear Weapons[I]. In the light of the wish expressed at the end of each of those letters, their text is reproduced below as Letter I.

2. On the same day, the Resident Representatives, of Denmark and of the United Kingdom also addressed complementary letters to the Director General, the text of which is reproduced below as Letter II. On that day also the Resident Representative of the United States sent a complementary letter, the text of which is reproduced as Letter HI.

3. Also on 22 August, the Resident Representatives of the Federal Republic of Germany , and of the Netherlands each addressed to the Director General a letter analogous to the above-mentioned Letters I and II, the text of which is reproduced below as Letter IV.

4. The attachments to the Letters I and IV, which consist in both cases of the same memoranda, are reproduced in the Appendix.

Letter I

> I have the honour to inform you that the Government of . . . . has had under consideration procedures in relation to exports of (a) source or special fissionable material, and (b) equipment and material especially designed or prepared for the processing, use or production of special fissionable material, in the light of its commitment under Article III paragraph 2 of the Treaty on tile Non- Proliferation of Nuclear Weapons not to provide such

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[1] Reproduced in document INFCIRC/ 140.

items to any non-nuclear-weapon State for peaceful purposes, unless the source or special fissionable material is subject to safeguards under an agreement with the International Atomic Energy Agency.

The Government of . . . . has decided to act in this context in accordance with the attached memoranda.

I shall be grateful if you will bring this information to the attention of all Members of the Agency.

Letter H

I have the honour to refer to my letter of today's date, and to inform you that, so far as trade within the European Community is concerned, the Government of . .. . will, where necessary, implement paragraphs 5 of the memoranda enclosed with that letter in the light of its commitments under the Treaties of Rome.

Letter 111

With reference to my letter of this date, concerning procedures of the Government of the United States of America in relation to exports of source and special fissionable material and of equipment and material especially designed or prepared for the processing, use or production of special fissionable material, I shall provide you shortly with additional information concerning the implementation by my Government of such procedures.

I would like to call attention to paragraph 6 of Memorandum B, enclosed with my letter, and to note that, in accordance with existing procedures of my Government, safeguards are required in relation to items of equipment and material exported from the United States of America, in addition to those specified in paragraph 2 of that Memorandum.

I shall be grateful if you will bring this information to the attention of all Members of the Agency.

Letter IV

I have the honour to inform you that the Government of . . . . has had under consideration procedures in relation to exports to any non-nuclear-weapon State for peaceful purposes of (a) source or special fissionable material, and (b) certain categories of equipment and material especially designed or prepared for the processing, use or production of special fissionable material.

The Government of . . . . has decided to act in this context in accordance with the attached memoranda. So far as trade within the European Community is concerned, the Government of . . . . will, where necessary, implement paragraphs 5 of the memoranda in the light of its commitments under the Treaties of Rome.

I shall be grateful if you will bring this information to the attention of all Members of the Agency.

APPENDIX

MEMORANDUM A

INTRODUCTION

1. The Government has had under consideration procedures in relation to exports of nuclear materials in the light of its commitment not to provide source or special fissionable material to any non-nuclear-weapon State for peaceful purposes unless the source or special fissionable material is subject to safeguards under an agreement with the International Atomic Energy Agency.

DEFINITION OF SOURCE AND SPECIAL FISSIONABLE MATERIAL

2. The definition of source and special fissionable material adopted by the Government shall be that contained in Article XX of the Agency's Statute. [1]

THE APPLICATION OF SAFEGUARDS

3. The Government is solely concerned with ensuring, where relevant, the application of safeguards in non-nuclear-weapon States not party to the Treaty on the N-on-Proliferation of Nuclear Weapons (NPT)[2] with a view to preventing diversion of the safeguarded nuclear material from peaceful purposes to nuclear weapons or other nuclear explosive devices. If the Government wishes to supply source or special fissionable material for peaceful purposes to such a State, it will:

(a) Specify to the recipient State, as a condition of supply, that the source or special fissionable material, or special fissionable material produced in or by the use the reef, shall not be diverted to nuclear weapons or other nuclear explosive devices; and

(b) Satisfy itself that safeguards to that end, under an agreement with the Agency and in accordance with its safeguards system, will be applied to the source or special fissionable material in question.

DIRECT EXPORTS

4. In the case of direct exports of source or special fissionable material to non-nuclear-weapon States not party to NPT, the Government will satisfy itself, before authorizing the export of the material in question, that such material will be subject to a safeguards agreement with the Agency, as soon as the recipient State takes over responsibility for the material, but no later than the time the material reaches its destination.

RETRANSFERS

5. The Government, when exporting source or special fissionable material to a nuclear-weapon State not party to NPT, will require satisfactory assurances that the material will not be re-exported to a non-nuclear-weapon State not party to NPT unless arrangements corresponding to those referred to above are made for the acceptance of safeguards by the State receiving such re-export.

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[1] See also para. 6 below.

[2] Reproduced in document INFCIRC/140.

MISCELLANEOUS

6. Exports of the items specified in sub-paragraph (a) below, and exports of source or special fissionable material to a given recipient country, within a period of 12 months, below the limits specified in sub-paragraph (b) below, shall be disregarded for the purpose of the procedures described above:

(a) Plutonium with an isotopic concentration of plutonium-238 exceeding 80%;

Special fissionable material when used in gram quantities or less as a sensing component in instruments; and

Source material which the Government is satisfied is to be used only in non-nuclear activities, such as the production of alloys or ceramics;

(b) Special fissionable material	50	effective grams;
Natural uranium	500	kilograms;
Depleted uranium	1000	kilograms; and
Thorium	1000	kilograms.

MEMORANDUM B

INTRODUCTION

1. The Government has had under consideration procedures in relation to exports of certain categories of equipment and material, in the light of its commitment not to provide equipment or material especially designed or prepared for the processing, use or production of special fissionable material to any non-nuclear-weapon State for peaceful purposes, unless the source or special fissionable material produced, processed or used in the equipment or material in question is subject to safeguards under an agreement with the International Atomic Energy Agency.

THE DESIGNATION OF EQUIPMENT OR MATERIAL ESPECIALLY DESIGNED OR PREPARED FOR THE PROCESSING, USE OR PRODUCTION OF SPECIAL FISSIONABLE MATERIAL

9 The designation of items of equipment or material especially designed or prepared for the processing, use or production of special fissionable material {hereinafter referred to as the "Trigger List") adopted by the Government is as follows (quantities below the indicated levels being regarded as insignificant for practical purposes):

2.1. Reactors and equipment therefor:

2.1.1. Nuclear reactors capable of operation so as to maintain a controlled self- sustaining fission chain reaction, excluding zero energy reactors, the latter being defined as reactors with a designed maximum rate of production of plutonium not exceeding 100 grams ● per year.

2.1.2. Reactor pressure vessels:

Metal vessels, as complete units or as major shop-fabricated parts therefor, which are especially designed or

prepared to contain the core of a nuclear reactor as defined in paragraph 2. 1.1 above and are capable of withstanding the operating pressure of the primary coolant.

2.1.3. Reactor fuel charging and discharging machines:

Manipulative equipment especially designed or prepared for inserting or removing fuel in a nuclear reactor as defined in paragraph 2. 1.1 above capable of on-load operation or employing technically sophisticated positioning or alignment features to allow complex off-load fueling operations such as those in which direct viewing of or access to the fuel is not normally available.

2.1.4. Reactor control rods:

Rods especially designed or prepared for the control of the reaction rate in a nuclear reactor as defined in paragraph 2. 1.1 above.

2.1.5. Reactor pressure tubes:

Tubes which are especially designed or prepared to contain fuel elements and the primary coolant in a reactor as defined in paragraph 2. 1.1 above at an operating pressure in excess of 50 atmospheres.

2.1.6. Zirconium tubes:

Zirconium metal and alloys in the form of tubes or assemblies of tubes, and in quantities exceeding 500 kg, especially designed or prepared for use in a reactor as defined in paragraph 2. 1.1 above, and in which the relationship of hafnium to zirconium is less than 1: 500 parts by weight.

2.1.7. Primary coolant pumps:

Pumps especially designed or prepared for circulating liquid metal as primary coolant for nuclear reactors as defined in paragraph 2. 1.1 above.

2.2. Non-nuclear materials for reactors:

2.2.1. Deuterium and heavy water:

Deuterium and any deuterium compound in which the ratio of deuterium to hydrogen exceeds 1:5000 for use in a nuclear reactor as defined in paragraph 2.1. i above in quantities exceeding 200 kg of deuterium atoms for any one recipient country in any period of 12 months.

2.2.2. Nuclear grade graphite:

Graphite having a purity level better than 5 parts per million boron equivalent and with a density greater than 1.50 grams per cubic centimetre in quantities exceeding 30 metric tons for any one recipient country in any period of 12 months.

2.3.1. Plants for the reprocessing of irradiated fuel elements, and equipment especially designed or prepared therefor.

2.4.1. Plants for the fabrication of fuel elements.

2.5..1. Equipment, other than analytical instruments, especially designed or prepared for the separation of isotopes of uranium.

Clarifications of certain of the items on the above list arc annexed.

THE APPLICATION OF SAFEGUARDS

3. The Government is solely concerned with ensuring, where relevant, the application of safeguards in non-nuclear-weapon States not party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT)[1] with a view to preventing diversion of the safeguarded nuclear material from peaceful purposes to nuclear weapons or other nuclear explosive devices. If the Government wishes to supply Trigger List items for peaceful purposes to such a State, it will:

(a) Specify to the recipient State, as a condition of supply, that the source or special fissionable material produced, processed or used in the facility for which the item is supplied shall not be diverted to nuclear weapons or other nuclear explosive devices; and

(b) Satisfy itself that safeguards to that end, under an agreement with the Agency and in accordance with its safeguards system, will be applied to the source or special fissionable material in question.

DIRECT EXPORTS

4. In the case of direct exports to non-nuclear-weapon States not party to NPT, the Government will satisfy itself, before authorizing the export of the equipment or material in question, that such equipment or material will fall under a safeguards agreement with the Agency.

RETRANSFERS

5. The Government,. when exporting Trigger List items, will require satisfactory assurances that the items will not be re-exported to a non-nuclear-weapon State not party to NPT unless arrangements corresponding to those referred to above are made for the acceptance of safeguards by the State receiving such re-export.

MISCELLANEOUS

6. The Government reserves to itself discretion as to interpretation and implementation of its commitment referred to in paragraph 1 above and the right to require, if it wishes, safeguards as above in relation to items it exports in addition to those items specified in paragraph 2 above.

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[1] Reproduced in document INFCIRC/140.

ANNEX

CLARIFICATIONS OF' ITEMS ON THE TRIGGER LIST

A. Complete nuclear reactors

(Item 2.1.1 of the Trigger List)

1. A "nuclear reactor" basically includes the items within or attached directly to the reactor vessel, the equipment which controls the level of power in the core, and the components which normally contain or come in direct contact with or control the primary coolant of the reactor core.

2. The export of the whole set of major items within this boundary will take place only in accordance with the procedures of the memorandum. Those individual items within this functionally defined boundary which will be exported only in accordance with the procedures of the memorandum are listed in paragraphs 2. 1.1 to 2.1.5. Pursuant to paragraph 6 of the memorandum, the Government reserves to itself the right to apply the procedures of the memorandum to other items within the functionally defined boundary.

3. It is not intended to exclude reactors which could reasonably be capable of modification to produce significantly more than 100 grams of plutonium per year. Reactors designed for sustained operation at significant power levels, regardless of their capacity for plutonium production, are not considered as "zero energy reactors"

B. Pressure vessels

(Item 2.1.2 of the Trigger List)

4. A top plate for a reactor pressure vessel is covered by item 2. 1.2 as a major shop-fabricated part of a pressure vessel.

5. Reactor internals (e. g. support ***columns*** and plates for the core and other vessel internals, control rod guide tubes, thermal shields, baffles, core grid plates, diffuser plates, etc.) are normally supplied by the reactor supplier. In ***some*** cases, certain internal support components are included in the fabrication of the pressure vessel. These items are sufficiently critical to the safety and reliability of the operation of the reactor (and, therefore, to the guarantees and liability of the reactor supplier), so that their supply, outside the basic supply arrangement for the reactor itself, would not be common practice. Therefore, although the separate supply of these unique, especially designed and prepared, critical, large and expensive items would not necessarily be considered as falling outside the area of concern, such a mode of supply is considered unlikely.

c. Reactor control rods

(Item 2.1.4 of the Trigger List)

6. This item includes, in addition to the neutron absorbing part, the support or suspension structures therefor if supplied separately.

D. Fuel reprocessing plants

(Item 2.3.1 of the Trigger List)

7. A "plant for the reprocessing of irradiated fuel elements" includes the equipment and components which normally come in direct contact with and directly control the irradiated fuel and the major nuclear material and fission product processing streams. The export of the whole set of major items within this boundary will take place only in accordance with the

procedures of the memorandum. In the present state of technology only two items of equipment are considered to fall within the meaning of the phrase "and equipment especially designed or prepared therefor". These items are:

(a) Irradiated fuel element chopping machines: remotely operated equipment especially designed or prepared for use in a reprocessing plant as identified above and intended to cut, chop or shear irradiated nuclear fuel assemblies, bundles or rods; and

(b) Critically safe tanks (e. g. small diameter, annular or slab tanks) especially designed or prepared for use in a reprocessing plant as identified above, intended for dissolution of irradiated nuclear fuel and which are capable of withstanding hot, highly corrosive liquid, and which can be remotely loaded and maintained.

8. Pursuant to paragraph 6 of the memorandum, the Government reserves to itself the right to apply the procedures of the memorandum to other items within the functionally defined boundary.

E. Fuel fabrication plants

(Item 2.4.1 of the Trigger List)

9. A "plant for the fabrication of fuel elements" includes the equipment:

(a) Which normally comes in direct contact with, or directly processes, or controls, the production flow of nuclear material, or

(b) Which seals the nuclear material within the cladding.

10. The export of the whole set of items for the foregoing operations will take place only in accordance with the procedures of the memorandum. The Government will also give consideration to application of the procedures of the memorandum to individual items intended for any of the foregoing operations, as well as for other fuel fabrication operations, such as checking the integrity of the cladding or the seal, and the finish treatment to the solid fuel.

F. Isotope separation plant equipment

(Item 2.5.1 of the Trigger List)

11. "Equipment, other than analytical instruments, especially designed or prepared for the separation of isotopes of uranium" includes each of the major items of equipment especially designed or prepared for the separation process.

APPENDIX B

U.S. Arms Control and Disarmament Agency
Press Release of February 23, 1976

U.S. Arms Control and Disarmament Agency

76-3

Please HOLD for release
10: 00 A. M. EST
Monday, February 23, 1976

In a statement prepared for delivery today before the Senate Subcommittee on Arms Control, international Organizations and Security Agreements (Committee on Foreign Relations) Dr. Fred C. Ikle (Ee-Clay) , Director of the U.S. Arms Control and Disarmament Agency, reported for the first time on two important U.S. initiatives to reduce the threat of further proliferation of nuclear weapons.

Following discussions with other exporters of nuclear equipment and technology, the United States will now follow a comprehensive set of principles governing nuclear exports. These are intended to serve as a further barrier to nuclear proliferation without hindering civil nuclear development to meet the world's energy needs. These rules involve more widespread application of International Atomic Energy Agency safeguards, strengthened requirements for physical security measures, restraint in exports of specified sensitive technologies, and stronger provisions governing the transfer and retransfer of equipment and technology.

The second U.S. initiative concerns promotion of multinational fuel-cycle centers as a long-term concept to head off the severe dangers of nuclear proliferation and terrorism stemming from further national development of reprocessing Plants. Emphasizing that our intention is not to Promote reprocessing, Dr.Ikle reported on IAEA and U.S. studies which have been initiated to find practical, economic alternatives to such national reprocessing.

STATEMENT OF FRED C. IKLE, DIRECTOR

United States Arms Control and Disarmament Agency
before the
Subcommittee on Arms Control, International
Organizations and Security Agreements
Committee on Foreign Relations
United States Senate
Monday, February 23, 1976

Mr. Chairman, and members of the Committee, I greatly appreciate this opportunity to appear before you.

This morning I would like to comment on two kinds of initiatives undertaken by the Arms Control and Disarmament Agency and the Executive Branch to deal with nuclear proliferation.

The first concerns nuclear exports, the second, multinational fuel centers.

The United States over the years has sought to work with other countries to insure that civil nuclear exports would be used only for peaceful purposes. We have recently had a number of bilateral and multilateral discussions with nuclear exporters to develop common rules on safeguards and export controls. As a result, the United States together with other exporters has decided to apply certain principles to our future nuclear exports. Nest of these are consistent with current U.S. practice; some are new. All are designed to inhibit the spread of nuclear weapons while permitting nuclear exports of equipment to meet the world's growing energy needs. These principles include the following:

-- The requirement that recipients must apply international **(IAEA)** safeguards on all nuclear imports.

-- The requirement that the importer give assurances not to use these imports to make nuclear explosives for any purpose -- whether called "peaceful" or not.

-- The requirement that the importer have adequate physical security for these nuclear facilities and materials to prevent theft and sabotage.

-- The requirement for assurances that the importers will demand the same conditions on any retransfer of these materials or types of equipment to third countries.

Now, on the question of more sensitive exports -- those which involve fuel enrichment, spent fuel reprocessing, and heavy water. We intend to use restraint in supply of these exports, particularly when we think they could add to the risk of proliferation,

In addition, in cases where we do export sensitive technology, we require that the importers obtain our consent before they re-transfer any sensitive nuclear technology to a third country.

These are the minimum standards the US will apply to its nuclear exports. We are prepared to be more stringent when appropriate.

Together with other leading exporters of nuclear technology, we are also committed to follow-up efforts along three lines.

1. To promote international cooperation in exchanging information on physical security, on measures of protection of nuclear material in transit, and on measures for recovery of stolen nuclear material and equipment;

2. To improve the effectiveness of IAEA safeguards through special efforts that support that organization, and

3. To encourage the designers and makers of sensitive equipment to construct it in a way that will aid safeguards.

Mr. Chairman, the second kind of initiatives we are undertaking have to do with multinational fuel-cycle centers.. The idea for such centers was promoted in the final declaration of the Review Conference of the Non-Proliferation Treaty held in Geneva last year. At the United Nations General Assembly last autumn, Secretary Kissinger stressed the grave danger of national reprocessing plants to nuclear proliferation and thus to world security, and proposed establishment of multinational fuel-cycle centers as a safer alternative to national control of reprocessing facilities.

The International Atomic Energy Agency has now begun a major study of the regional multinational center concept; the United States actively supports it, and I expect it will be completed sometime next year. Preliminary results suggest that

large scale centers could bring significant economies of scale compared with smaller national reprocessing plants. But more important from my perspective -- these centers may be an attractive alternative to national reprocessing plants, particularly for countries with more limited nuclear capacity. This alternative then may encourage countries to forego national reprocessing facilities and work together. This would make safeguards -- and the protection of dangerous nuclear materials more effective. In short, if the concept proves successful, multinational centers should reduce the dangers of further nuclear proliferation and of nuclear terrorism.

The Arms Control and Disarmament Agency has strongly supported the IAEA study by supplying experts and consultants. We have also begun our own study on a broad range of related questions. One such question is whether new approaches to storing spent fuel could forestall premature national reprocessing; another is how to better manage transportation of nuclear materials. We are also beginning a preliminary study of the practical steps the U.S. -- both government and industry -- might take to advance the concept of multinational centers abroad,

I was asked recently why ACDA wishes to build reprocessing plants, The question indicates a misunderstanding of our objectives, Our efforts for multinational approaches should not be misunderstood: we do not wish to promote the reprocessing of Plutonium. On the contrary, Our hope, in all these efforts, is to investigate practical, economic alternatives to national. reprocessing, and thereby reduce the growing dangers of nuclear proliferation,

Mr. Chairman, this completes my initial remarks. I would be pleased to answer your questions concerning these initiatives or any other aspects of our non-proliferation efforts, past or present.

APPENDIX IX-E

NUCLEAR SUPPLIERS CONSULTATION - 2

by

Stieff Research and Development Co., Inc.

Suppliers Consultations - 2

In the Fall of 1974 the United States began a series of bilateral discussions with a small group of nuclear supplier states and potential nuclear supplier states for the purpose of determining whether a common set of principles could be evolved which would govern the action of the States in the area of nuclear exports. These discussions, which were conducted under a cloak of secrecy which has continued until this day, led to the formation of what is now known as the Nuclear Suppliers Group. Although the secrecy which has surrounded these activities has extended to the members of the Group, it is now generally conceded that the United States, Canada, the USSR, Japan, France, Germany and the United Kingdom were involved in these early discussions.

The initial concerns of the nuclear suppliers found their first formal expression in the final declaration of the NPT Review Conference (40) held in Geneva from May 5th to the 30th of 1975. This declaration, accepted by consensus urged that:

(a) “in all achievable ways, common export requirements relating to safeguards be strengthened, in particular by extending the application of safeguards to all peaceful nuclear activities in importing states not Party to the Treaty;

(b) “such common requirements be accorded the widest possible measure of acceptance among all suppliers and recipients;

(c) “all Parties to the Treaty should actively pursue their efforts to these ends.”

The Conference also urged that actions be pursued to elaborate further, within the IAEA, concrete recommendations for physical protection of nuclear materials in use, storage or transit with a view to ensuring a uniform, minimum level of protection and called upon the States to give the earliest possible effective application to the IAEA's recommendations within the framework of their respective physical protection systems.
Finally, the Conference noted that a number of nuclear supplier states had adopted certain minimum, standard requirements for IAEA safeguards in connection with their exports to non-nuclear weapon States not Party to the Treaty and the Conference attached particular importance to the condition, established by those States of the undertaking not to divert to nuclear weapons or other nuclear explosive devices.

When it is recalled that the attendance at the Convention included 58 States Party to the NPT, and seven States signatory but not Party as well as seven addition States with representation, the significance of the consensus can be more fully appreciated. Only France among the nuclear supplier states is not now a part to the Treaty.

The efforts of the nuclear suppliers, including France, to develop a common export and safeguards policy has been described by both Mr. George Vest, Director of Politico-Military Affairs (41) and Secretary Kissinger (42) in testimony before Congress. Although their remarks were severely constrained by the confidential nature of the suppliers consultations they did announce the adoption by the United States of certain minimum principles. These principles include:

- provisions for the application of IAEA Safeguards on all nuclear exports.

- prohibition of the use of any U.S. export to make any nuclear explosive device - peaceful or not.

  requirement of adequate physical protection of nuclear facilities and material against theft or sabotage.

  requirement for similar safeguards and physical protection on any re-export or transfer of these materials or equipment to third countries.

  requirement of special conditions governing sensitive materials and technology.

The contribution of the NPT Review Conference declarations to the formulations of the export and safeguards principles of the nuclear suppliers is obvious. These principles, which the United States has announced it will apply to its exports, is a unilateral declaration. The announcement does not reflect a treaty commitment and is not a legal or binding obligation. However, the United States as well as the other nuclear suppliers do have a substantial political investment in these principles and would not abandon them lightly.

The effectiveness of this informal arrangement will be determined most probably on the basis of the actions which the other Nuclear Supplier States take with regard to the safeguard conditions which they apply to the export of their nuclear materials, equipment and technology. The recent decision by the French president, Monsieur Giscard d'Estang to form a cabinet level committee to coordinate and supervise French nuclear exports is a very encouraging development. The impact of this development on French nuclear export policy will be followed with great interest.

An important statement of Canadian nuclear policy was made in the House of Commons on December 22, 1976. This unilateral export policy declaration states that:

> "Canadian reactors and uranium shipments to non-nuclear weapon states under future contracts will be restricted to those which ratify the Non-proliferation Treaty or otherwise accept international safeguards on their entire nuclear programme. It follows from this that Canada will terminate nuclear shipments to any non-nuclear state which explodes a nuclear device."

Existing Canadian export policy included a binding assurance that Canadian materials and technology could not be used for explosive purposes. The new policy closes a gap by including not only what a State might receive from other than Canadian suppliers but also what it might do on its own, as in the case of India. In this way Canada will have an assurance that its nuclear customers will have been selected only from those countries which have made a clear and unequivocal commitment to the non-proliferation of nuclear weapons.

In concluding the statement to the House, Canada urged the other suppliers to take a collective decision to:

> "restrict their nuclear exports to those non-nuclear weapon states which have ratified the Non-proliferation Treaty or otherwise accept full-scope safeguards. We regret that to-date it has not been possible to reach a collective decision to this effect . . . With this announcement I am calling on other nuclear exporters to review their own export policies not in the light of commercial gain but in the interest of maintaining a safe and secure world."

Prior to the Canadian statement, on October 28, 1976, President Ford issued a major announcement on U.S. nuclear policy (8, op. cit.). This document, the product of intense debate and negotiation within the Executive Branch of the Government reflects and implements in many ways the declarations of the NPT Review Conference and the principles developed during the supplier consultations. Above all, it reflects a renewed and urgent concern with the dilemma of the fissionable atom and the clear threat to the security of all that will accompany the continued spread of nuclear weapons and their technology around the world.

President Ford announced a decision to greatly accelerate U.S. initiatives in conjunction with both nuclear supplier and consumer nations to control the spread of plutonium and technologies for separating plutonium and proposed a three-year moratorium on the export of reprocessing and enrichment technologies and facilities. New criteria were also announced for determining whether to expand or enter into new agreements for nuclear cooperation which include:

- Adherence to the NPT which will be a strong positive factor.
- Willingness to submit to full fuel cycle safeguards pending adherence to NPT will receive positive recognition, as will
- Willingness to forego or postpone decisions to establish a national reprocessing or enrichment plant, or
- Willingness to participate in the storage of spent fuel and separated plutonium under an international regime.

President Ford has also directed the Secretary of State to pursue vigorously the problem of physical security and a possible international convention as

well as the substantial strengthening of the IAEA safeguards System. Finally, the President, addressed the question of sanctions against States which violate their nuclear safeguards agreements. The minimum U.S. response regardless of whether the diverted material was of U.S. origin would be the immediate termination of our agreements for cooperation and fuel supply. Additional steps are implied not necessarily related to nuclear matters, including consultations with all interested nations to determine appropriate additional action.

It is to be hoped that the remaining nuclear suppliers will issue similar statements of their revised and strengthened export policies. Such concerted action may be increasingly difficult to obtain.

Recently, it has been reported in the press that the membership of the Nuclear Suppliers Group has been substantially expanded to include the Netherlands, Belgium, Sweden, the German Democratic Republic, Poland and Czechoslovakia.

It seems clear that the larger Group could consolidate many of the gains that have been made to date and that this Group might consider some additional non-proliferation initiatives. The enlargement of the Group is not, however, without some drawbacks; the most obvious being the increased difficulty in obtaining a consensus with States with very diverse interests which include both export and import of nuclear materials and technology. The informal nature of the suppliers consultations, however, may provide an essential ingredient in the difficult process of changing long standing national policies.

APPENDIX IX-F

MULTINATIONAL AND INTERNATIONAL FUEL CYCLE FACILITIES

by

Ted Greenwood

MULTINATIONAL AND INTERNATIONAL FUEL CYCLE FACILITIES

Any nuclear power reactor produces as a necessary by-product of its operation fissile material that could be separated from the spent fuel by chemical means and used in the fabrication of nuclear explosive devices. For all reactor types now commercially available or expected to be available during the next decade, the relevant fissile by-product of power production is plutonium.* One of the most important proliferation-related issues that emerges out of the gradual international diffusion of nuclear power technology, therefore, is how the spent fuel and particularly its plutonium contents will be handled.

Basically two options are available. States may choose to reprocess spent fuel to separate the plutonium and uranium from each other and from the highly radioactive fission products and other actinide elements that are produced as the fuel burns or they may choose not to do so. The benefits of reprocessing are the recovery of uranium and plutonium for reuse in power reactors, and the reduction in volume of high level nuclear waste that must be isolated from the environment for tens to hundreds of thousands of years. Whether states will prefer to reprocess or store spent fuel depends on the relative economics (which are currently very uncertain[2]) of reprocessing and recycle versus the so-called throw-away option; their preferred method for handling nuclear wastes; and the extent to which they see non-economic incentives to recycle recovered uranium and plutonium. Such incentives might derive from a

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*One high temperature gas reactor, operating on a thorium-uranium-233 fuel cycle is now in operation in the United States. Despite German and some continuing American interest in this technology, however, such reactors do not now appear likely to contribute significantly to nuclear power programs over the next decade. A thorium-uranium fuel cycle could be used in today's light- and heavy-water reactors and proposals to do so have been made.[1] Nonetheless, this again seems unlikely to play a significant role over the next decade.

desire to reduce dependence on imported uranium or the purchase of uranium enrichment services or to gain experience with plutonium fuel in anticipation of ultimate reliance on plutonium breeder reactors.[3]

In anticipation of the possibility that a number of non-nuclear countries will, for one reason or another, choose to reprocess their spent fuel, considerable attention has focused on possible mechanisms to reduce the likelihood that widespread reprocessing and the use of plutonium in reactor fuel will contribute to the proliferation of nuclear weapons. One possibility is for the United States and other states with advanced nuclear industries to use exhortation, example, provision of alternatives through the market, or some combination of these to persuade other states not to reprocess. Another is to encourage states not to build their own reprocessing facilities. A ban on the international transfer of reprocessing facilities or technology is widely thought in the United States to be reinforcing of both objectives.* Reliance on spent fuel storage facilities or sufficient reprocessing capacity under national control in nuclear or low-risk non-nuclear countries to provide storage or reprocessing services to other states is also frequently suggested as a means of dissuading states from building their own reprocessing plants. Finally, the creation of such facilities under multinational control has also been proposed to serve the same purpose. One multinational reprocessing facility, the Eurochemic plant in Mel, Belgium, has already been built but is no longer operating.

The fuel for most power reactors now in use and expected to be available at least through the end of the century requires uranium that has been partially enriched in the U-235 isotope. Although such low-enriched uranium cannot be used for explosives, any enrichment facility can (with an economic penalty dependent on the technology used) be employed to produce high-enriched, weapons grade uranium. Substantial concern also applies to the spread of enrichment technology, therefore,

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*For the role of the nuclear suppliers' conference in regulating the international diffusion of this technology, see the submission entitled "The Suppliers Conference."

although in this case the fact that the material produced in normal operations would not be weapons grade somewhat reduces the risks compared to the reprocessing case. Multinational facilities (MNFs) have again been proposed as a means of preventing the diffusion of enrichment technology and facilities to non-nuclear states. In fact two multinational organizations, Urenco /Centec and Eurodif already exist for the purpose of providing enrichment services.

A few commentators on the subject of nuclear proliferation and the nuclear industry have suggested going beyond the creation of multinational facilities to truly internationalizing these components of the industry.[4] Unlike a multinational arrangement which would involve a limited number of participating states with each or at most a few facilities under the control of any given multinational organization, the international approach would have one organization, perhaps the IAEA, which has open and perhaps close to universal membership own or control all (or at least most) such facilities in the world.

Advantages and Disadvantages

There are several possible advantages of MNFs that might persuade states to rely on them rather than build their own reprocessing or enrichment plants. First, they would serve as mechanisms for mobilizing the technical personnel and know-how of advanced industrial states to provide a service for which smaller, less advanced states might otherwise have to become dependent on the industrialized states. Second, by serving a larger market than would national plants in countries with small nuclear industries, economics of scale are possible and the cost of services could be reduced. Third, if spent fuel were stored at an MNF or if high level wastes separated by reprocessing were not returned to the country of origin, the MNF would solve the waste management problem which for many states is very difficult. Fourth, participation in an MNF might serve as a mechanism for a state to acquire sufficient technical expertise to build its own facilities at a later date. From a non-proliferation. perspective the safeguarding and physical protection of a single, large MNF might be easier and more certain than of many smaller, national facilities. Compared to relying on services purchased from nuclear supplier nations, MNFs might provide the further

advantages of greater security of supply and at least partial satisfaction of symbolic or nationalistic objectives that might prompt some developing states to acquire indigenous facilities as a demonstration of their ability to create and manage complex technological enterprises.

Proponents of the international approach claim that it would have all of these same advantages. Their major additional asset would be their ability to mollify more successfully the "sense of inequality, resentment against what is perceived as discrimination, and a desire for equivalent rights and status"[5] on the part of developing states.

Disadvantages of MNFs are of three kinds: those common to any facility, those pertaining to both enrichment and reprocessing facilities, and those pertaining only to facilities that provide reprocessing. Participation in any MNF would to some extent reduce the freedom of individual action of participating states in organizing and managing their domestic industries. In addition, the problems of designing the institutional and legal structure and of successfully initiating, constructing, and operating any MNF would be very severe, perhaps so severe that failure, unacceptable delays or insecurities in the supply of services would be anticipated or realized. The possibility of technology transfer cited above as a potentially attractive feature of an MNF for small nuclear states can also be seen as a serious disadvantage from a non-proliferation perspective when reprocessing or enrichment were involved.

Support for a MNF that included reprocessing would weaken the case that reprocessing itself should be foregone or delayed. If significantly subsidized by nuclear states in an effort to encourage participation, an MNF would obscure or undermine the natural market forces that might otherwise tend to discourage reprocessing. In any case, the argument against reprocessing would be more difficult to sustain in the face of a major multinational effort to create a reprocessing facility.

More serious, once plutonium were separated at an MNF it must be prevented from finding its way into national explosive programs. Reprocessing in a MNF and shipping the recovered plutonium back to the state of origin, even if under safeguards, would be no better than having

each state with its own safeguarded reprocessing plant and plutonium storage area. Mechanisms must be found, therefore, if a MNF with reprocessing is to be useful from a rim-proliferation perspective, to prevent such automatic return of plutonium. Several possibilities are available. In order to persuade states not to use plutonium fuel at all, they could be offered an equivalent amount of uranium fuel in exchange for their plutonium. Such an arrangement would require the cooperation of at least some suppliers of enrichment services and perhaps also some uranium producers. Alternatively, states could be shipped their plutonium, but only under strict safeguards and in quantities required for fairly immediate use in their reactors. To implement this procedure the MNF would have to include a plutonium storage facility and almost certainly a mixed-oxide fuel fabrication capability.

A MNF that provided only spent fuel storage services would not experience these difficulties associated with reprocessing. It would in addition have many fewer technical and administrative demands made of it and probably be easier and quicker to create than a larger and more complex facility that included a reprocessing plant and other back-end facilities. While not a substitute for national reprocessing for states determined to recycle plutonium, a multinational spent fuel storage facility would be quite sufficient for those states whose only interest is dealing with nuclear wastes.

The disadvantages of international control of fuel cycle facilities are again the same as those for multinational control, except significantly stronger. Particularly the problems of institutional design, distribution of power and efficient operation would appear to be very serious in the international case, even if the IAEA were used as the relevant organizational entity.

Analyses of MNFs

Beyond the internal analyses of international or multinational control of fuel cycle facilities that have been conducted within the U.S. and perhaps other governments, two significant studies have been undertaken. The first is the Regional Nuclear Fuel Cycle Center (RFCC) Study of the IAEA, initiated in 1975 following a preliminary study the

previous year. The second was the 26th Pugwash Symposium, International Arrangements for Nuclear Fuel Reprocessing, held in May 1976 under the joint sponsorship of the Canadian and American Pugwash Groups. Both have focused on the back end of the fuel cycle and on multinational arrangements only. Much, but not all, of the analysis carries over directly, however, to the enrichment case and international arrangements.

1. IAEA Region Nuclear Fuel Cycle Center Study

The IAEA study was initiated in response to the interest of member states in the MNF concept. It is intended "to assist the Member States in evaluating the relative merits of the RFCC approach to establishing fuel cycle facilities."[6] As described by the Study's director its specific objectives are:

1. "To develop the methodology for assessment of alternative strategies for establishment of integrated regional nuclear fuel cycle centres, so as to evaluate their advantages and disadvantages vis-a-vis dispersed fuel cycle facilities.
2. "To prepare a report on this methodology, including illustrative examples on approaches and advantages to Member States, for the use of those organizations interested in the implementation of nuclear fuel cycle activities.
3. "To provide a mechanism for the establishment of a forum where Member States and other interested parties can work out alternative strategies with regard to nuclear fuel cycle activities as well as evolve appropriate frameworks to cover institutional, legal and other aspects related to the establishment of such multinational fuel cycle centers."[7]

A small internal staff at the IAEA is relying heavily on consultants from member countries to provide technical, financial and other relevant input data. The technologies to be considered cover the entire back end of the fuel cycle: spent fuel transport, spent fuel storage, reprocessing, mixed oxide fuel fabrication, and waste management. The study also includes the possibility that spent fuel would be stored for a long period prior to reprocessing. Besides an analysis of economics and materials flow for which computer simulation and optimization models

have been constructed, the study will examine institutional and legal aspects; organization and administrative aspects; financial considerations; health, safety and environmental aspects, safeguards, physical security and process controls; and public acceptance considerations.[8] A report on Institutional - Legal Framework Aspects was issued in July 1976.[9] A summary report with illustrative analyses of alternative fuel cycle strategies is expected to be presented to the Conference on Nuclear Power and its Fuel Cycle to be held by the IAEA is Salzburg in May 1977.

Several significant results have already emerged from the IAEA study. First, despite the emphasis on the regional nature of MNFs in the study's name and original conception, this notion has now largely been abandoned because of the recognition that transportation costs are small enough to preclude significant economies arising out of geographical proximity.[10] Second, at least one participant in a MNF would have to bring to the project rather extensive technical know-how and industrial support and to provide or arrange for a major part of the financing. Thus, a MNF cannot be a consortium only of states with immature nuclear industries. The assistance and support of at least one of the major nuclear supplier countries is thought to be necessary.[11] Third, there appears to be important financial benefit to be derived from states joining forces to build multinational facilities rather than building their own national ones. This financial incentive is thought to be a major incentive for states to participate.

Fourth, great flexibility and variation is possible for the institutional and legal structure that would underlie an MNF. Indeed substantial variation already exists among the three current MNFs, Eurochemic, Eurodif and Urenco/Centec.* Existing multinational enterprises that can serve as useful models for a MNF include not only these three but also Intelsat, Scandinavian Airlines System, Central American Air Navigation Service Corporation and European Company for the Financing of Railways.[13]

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*United Reprocessors, while a multinational enterprise does not own plants or provide services. It is therefore not a useful model for a MNF.[12]

2. Pugwash Symposium on International Arrangements for Nuclear Fuel Reprocessing[14]

The Pugwash Symposium examined the possible motivations for reprocessing in general and for reprocessing in MNFs in particular. It compared reprocessing at national facilities and MNF along the dimensions of economics, safeguards, health and safety, waste management, and physical security. It concluded

> "with reasonable clarity that multinational operation need not necessarily entail a penalty on any of these dimensions. Indeed, in some respects the multinational approach holds out the possibility of substantial gains."[15]

The major potential gains were found to be in economics of scale compared to many small plants, and in facilitating safeguards and physical security.

The Symposium recognized the concern of all participant states for security of supply and the special sensitivities of developing country participants concerning their being provided a full and equal share in the enterprise. It also recognized the problems of ultimate disposal of plutonium and of technology transfer. Dealing adequately and simultaneously with all of these concerns was seen to be a very demanding task. As stated in the Symposium paper on institutional arrangements, "The overarching tension or trade-off is that between the commercial and political aspects of the enterprise."[16]

The institutional analysis stressed both the variety of mechanisms available and the difficulty of creating a MNF. It stressed the need for a high degree of governmental involvement and of increasing size, functional complexity and membership from a modest beginning. Spent fuel storage was seen as an appropriate function with which to begin,

Institutional and Political Issues

Some of the institutional and political issues that must be addressed in considering multinational or international facilities have already been mentioned. The most important ones revolve around membership, distribution of power, the political-commercial tension, access to technology, and the role of the IAEA. It is the existence of such issues

that constitutes the important distinction between these institutional arrangements and national facilities. The extent to which they can be adequately resolved will determine both the feasibility and value of multinational or international facilities. Answers to detailed questions about the instrumentality by which the enterprise would be launched and given legal status, (whether it be an intergovernment treaty or the creation of a traditional shareholding company for example), and whether new or existing entities would be charged with management and operations would flow directly from the manner in which these more fundamental issues are resolved.

Membership in a MNF could be determined on the basis of geography, historical ties between governments or commercial enterprises within participating states, or shared common interests and plans for nuclear development. There appears to be agreement that at least one technically advanced state must participate in a multinational venture, but whether as a regular member or not is not definite. For a MNF membership would. presumably be closed to the initial interested parties or to other states acceptable to them. An international arrangement would, by definition, be open to participation by any state. One special case of an MNF is of particular interest. This is a bilateral arrangement for joint control of a reprocessing or enrichment facility between a nuclear supplier state and its customer. Such an arrangement might significantly reduce the risk of diversion from transferred sensitive facilities.

Distribution of power within the venture will be an important issue. If states are to forego their option to build domestic reprocessing or enrichment plants and are to feel secure in their dependence on a multinational or international facility, they must be assured through an appropriate distribution of power over policy and operations that their interests will be protected. That is, the structure of the organization must be politically acceptable to participating governments. This may be assured by careful drafting of an enabling treaty instrument, by a requirement for consensus on important decisions, by appropriate

distribution of voting rights and specifying different majority requirements for different issues, by division of responsibility among a number of decision making bodies following different procedures or by some combination of these.

There will be a tension within any multinational or international facility between the desire to operate efficiently on a commercial basis and the need to be responsive to a variety of (sometimes contradictory) political objectives. While governments will inevitably be directly involved in oversight and plotting policy directions, day to day management and supply of services should be protected as much as possible from political interference. Whether this means creating a multinational commercial enterprise to manage the facility or contracting with a single private concern to do so is a matter of choice.

If a facility that includes reprocessing or enrichment is not to serve as a mechanism by which participating states can increase their own technological base for the purpose of eventually initiating national plants, limitations must be imposed on the transfer of technology or on the purposes to which acquired technology may be put. Competing with this will be the desire of developing states to use their participation in the arrangement to increase their level of technological sophistication. This is a fundamental issue that will be difficult to resolve.

The role of the IAEA can certainly be to provide technical assistance and a facilitating mechanism for the creation of a multinational or international facility. It would also no doubt be called on to provide safeguards. Article 1X.1.1 of the IAEA Statute authorizes the Agency to "establish or acquire . . . . plant, equipment, and facilities for the receipt, storage, and issue"[17] of nuclear materials. It therefore presumably already has authority to establish an international spent fuel storage facility under its control. The Agency cannot of course act to do so without authorization from the Board of Governors or perhaps the General Conference. Whether or not its mandate under Article III, Functions, could be interpreted broadly enough to permit its direct operation of a reprocessing or enrichment plant or whether its mandate should be appropriately extended are matters that must be decided by the Governing Board and Member States.

Evaluation

In assessing its utility from a non-proliferation perspective, any multinational or international fuel cycle facility must be compared to the alternatives of facilities under national control in non-nuclear states and relying on other mechanisms to dissuade states from reprocessing or relying on their own sensitive facilities. The primary alternative mechanisms of dissuasion would be, in the case of reprocessing, assuring states of sufficient supplies of enriched uranium to obviate their desire to recycle plutonium and move rapidly to breeders and, for enrichment and reprocessing providing sufficient capacity in nuclear or low-risk non-nuclear states that others would be content to rely on for delivery of services.

The obstacles to establishing a truly international mechanism for owning and operating fuel cycle facilities seem greatly to outweigh the anticipated benefits compared to other alternatives. It does not, therefore, appear to be a fruitful avenue for study or for policy initiatives. The relative lack of attention given this option, seems completely appropriate.

Despite the widespread concern of only a few years ago that the coming decade would see a shortage of enrichment capacity or at least a very tight market for enrichment services, this no longer appears to be the case. Over the next ten to fifteen years there is in fact a high likelihood that excess enrichment capacity will exist in the world and that the major policy question for supplier countries, particularly the United States, is whether or not to build enriched uranium stockpiles. In addition, the number of commercial suppliers of enrichment services is diversifying compared to the past when the United States was the only one. No urgency currently exists, therefore, for the international community to stimulate the expansion of enrichment capacity at MNFs or otherwise. Two of the new enrichment suppliers have in fact been established as MNFs in order to share both the financial cost and enter-preneurial risks. Urenco/Centec involves companies and the governments of Britain, Holland and West Germany in the provision of enrichment services using centrifuge technology. Eurodif is a commercial venture

with participation from government agencies or private entities in France, Belgium, Italy, Spain and Iran. Except for Iran there is no participation in these MNFs from developing countries towards whom the multinational concept is primarily directed. Nonetheless, given the anticipated excess and diversity of supply, there appears to be little incentive at present to stimulate the creation of a new MNF with broader developing country participation.

The primary interest in MNFs, therefore, is for the back end of the fuel cycle. Except for the small number of states with reprocessing plants operating or close to completion, no long term spent fuel storage, uranium-oxide fuel reprocessing or nuclear waste management capability exists. There is however a growing demand for such services in every country with a current or anticipated nuclear industry. The focus *to* date on MNFs for reprocessing and spent fuel storage is, therefore, totally appropriate. The concept does appear in this case to have some potential net benefit as a mechanism for reducing the likelihood that the diffusion of nuclear power technology will contribute to nuclear weapons proliferation.

The strongest case can be made for a MNF that would take and store spent fuel. Offering such a solution to the waste management problem of states not now particularly interested in recycling plutonium would reduce their incentives to reprocess either domestically or abroad. Of course a national enterprise that offered such services on a commercial basis would be equally useful, but seems unlikely to come into existence because of the universal reluctance on the part of countries to serve as a nuclear dumping ground. This same reluctance might preclude the establishment of a MNF for that purpose, since it must be actually sited within some country's boundaries. There is some chance, however, that the multinational nature of the facility and its important role in aiding the cause of non-proliferation would mitigate the opposition.

An assessment of the utility of MNFs for reprocessing depends on expectations concerning states' decision to reprocess and the growth of the commercial reprocessing industry as now constituted. If expectations are high that most states with emerging nuclear industries can be persuaded not to reprocess, no action should be taken now to initiate a MNF with

reprocessing. If, to the contrary, many such states are expected to seek mechanisms to reprocess their spent fuel, the question becomes how to persuade them not to build their own national facilities. Unlike the enrichment case, reliance on existing or anticipated excess reprocessing capacity in advanced industrialized states does not appear viable. Great uncertainty exists concerning the reprocessing industry in the United States. Japan is unlikely to have excess capacity in the foreseeable future. The only sure suppliers of services are the European partners of United Reprocessors. But even here, the West Germans face serious difficulties of public acceptance of their planned 1500 tonne per year plant and expansion of capacity by Britain and France is not assured. Even if significant capacity could be made available by United Reprocessors countries to the international market, many states might well be reluctant to rely on a single foreign supplying entity and to pay the high prices that United Reprocessors is demanding. In this case, therefore, the creation of one or more MNF might well be desirable.

Little can be done until the report of the IAEA Study is delivered and studied in depth. If, as is likely, the Study finds MNFs feasible and economically advantageous, action could then be taken by the United States, by other suppliers or through the suppliers' conference to stimulate interest in a specific MNF project. Stimulation is all that will be possible, however. The major interest and initiative must come from the states that would be the primary users of the facility. As pointed out by those analyzing institutional arrangements for the Pugwash symposium,

> "any effort to cajole - not to say coerce - participation in a multinational fuel cycle enterprise would be wholly misplaced. A reluctant partner would have available an infinitude of points and issues to create plausible, irritating, and ultimately defeating delay and complication in the negotiating process. Only assent freely given in the perception that the enterprise really serves the interests-of the countries involved will be able to surmount the many institutional problems that will inevitably arise."[18]

Furthermore, while an MNF for reprocessing might well provide economic and security of supply advantages to its participating states, it will contribute to the objectives on non-proliferation only if provisions are built in to protect against states ultimately building national plants with technology acquired from the MNF and if an alternative is found to shipping large quantities of plutonium, even under safeguards, back to the participating states.

Given the apparent agreement of those who have studied the MNF concept that modest beginnings stand the greatest chance of success, economics of reprocessing, there may be considerable advantage in proceeding in stages. Starting with a spent fuel storage facility would avoid an early commitment to reprocessing, assist immediately with the waste management problem and provide a period of modest demands for the MNF to prove its ability to function and gain the confidence of participating states. If initially chartered with a mandate to expand into reprocessing and mixed oxide fuel fabrication and if sited appropriately, a MNF that initially provides only spent fuel storage services could be expanded later. This is an approach very worth considering.

1. See Harold A. Fieveson and Theodore Taylor, 'Alternative Strategies for International Control of Nuclear Power', in Ted Greenwood, Harold Fieveson and Theodore Taylor, Nuclear Proliferation: Motivations, Capabilities and Strategies for Control (New York: McGraw-Hill, 1977), and S. Banerjee, E. Critoph and R.G. Hart, "Thorium as a Nuclear Fuel for CANDU Reactors", The Canadian Journal of Chemical Engineering, 53 (June 1975), pp. 291-296.
2. See Mark Sharefkin, "The Simple, Uncertain Economics of Multinational Reprocessing Centers", in Abram Chayes and W. Bennett Lewis (editors), International Arrangements for Nuclear Fuel Reprocessing, (Cambridge, Mass.: Ballinger Publishing co., 1977), pp. 47-64; and Ted Greenwood, George W. Rathjens, and Jack Ruina, "Nuclear power and Weapons Proliferation", Adelphi paper 130, (London: International Institute for Strategic Studies, 1977), pp. 18-20.
3. For a full discussion on motivations for reprocessing, see Ted Greenwood, "Why Reprocess?" in Chayes and Lewis, pp. 17-29.
4. See Lincoln P. Bloomfield, "Nuclear Spread and World Order", Foreign Affairs, Vol. S3, (July 1975), pp. 743-755; and David E. Lilienthal, "If This Continues, the Cockroach Will Inherit the Earth", The New York Times, (June 20, 1975), p. 33.
5. Bloomfield, p. 746.
6. International Atomic Energy Agency, "IAEA Study Project on Regional Nuclear Fuel Cycle Centers, Status Report", (September 1976), IAEA-RFCC/3, p. 1.
7. Vinay Meckoni, "Regional Nuclear Fuel Cycle Centers", IAEA Bulletin, Vol. 18, No. 1, p. 5.
8. IAEA-RFCC/3, p. 8-9.
9. International Atomic Energy Agency, 'Regional Nuclear Fuel Cycle Centre Study: Institutional-Legal Framework Aspects', IAEA-RFCC/2, (July 1976).
10. IAEA-RFCC/3, p. 2.
11. IAEA-RFCC/3, p. 2.

12. For a description of Urenco/Centec and United Reprocessor, see C. Allday, "Some Experiences in Formation and Operation of Multinational Uranium-Enrichment and Fuel-Reprocessing Organizations", in Chayes and Lewis, pp. 177-187. IAEA-RFCC/2 provides a discussion of Eurochemic, EURODIF and URENCO. See pages 8-11.
13. IAEA-RFCC/2 briefly discusses these on p. 12. See also Eugene B. Skolnikoff, "Relevance of Intelsat Experience for Organizational Structure of Multinational Nuclear Fuel Facilities", in Chayes and Lewis, pp. 223-232.
14. The Proceedings of this Symposium are given in Chayes and Lewis.
15. Constance B. Smith and Abram Chayes, "Institutional Arrangements for a Multinational Reprocessing Plant", in Chayes and Lewis, p. 145.
16. Smith and Chayes, p. 148.
17. Statute of the International Atomic Energy Agency Article 1X.1.1.
18. Smith and Chayes, pp. 17S-176.

APPENDIX IX-G

SANCTIONS

HUDSON INSTITUTE

Final Report

THE ROLE OF SANCTIONS IN NON-PROLIFERATION STRATEGY

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THE ROLE OF SANCTIONS IN NON-PROLIFERATION STRATEGY

Introduction

In addition to seeking to reduce the pressures for acquiring nuclear weapons, non-proliferation strategy may seek to increase constraints upon prospective proliferators. This report examines one possible means for doing so: the imposition of sanctions for safeguards agreement violations and other proliferatory activities. Beginning with a brief review of the current status of sanctions, it then discusses the purposes possibly served by sanctions; specific triggering activities and the broader contextual situation of a decision to impose sanctions; potential risks and consequences of sanctions; and components of a sanctions strategy, including enumeration of specific sanctions. It concludes with an overall evaluation of sanctions' potential role within non-proliferation policy.

The Current Situation

The threat of sanctions as a means of enforcing legal obligations already is included within American Agreements for [Nuclear] Cooperation with various countries; the International Atomic Energy Agency Statute; the Foreign Assistance Act as recently amended by the International Assistance and Arms Export Control Act of 1976; and former President Ford's October 28, 1916, statement on nuclear policy. These provide a starting point for the remaining discussion and the relevant aspects of each should be noted briefly.

First, American Agreements for Cooperation provide that in the event of non-compliance with the Agreement's provisions--e.g., those

guaranteeing non-military uses of the material, equipment, and devices transferred--the United States has the right "...to suspend or terminate this Agreement and to require the return of any materials, equipment, and devices [transferred under it]."

Second, Article XII (c) of the IAEA Statute provides that

> The inspectors shall report any non-compliance to the Director General who shall thereupon transmit the report to the Board of Governors. The Board shall call upon the recipient State or States to remedy forthwith any non-compliance which it finds to have occurred. The Board shall report the non-compliance to all members and to the Security Council and General Assembly of the United Nations. In the event of failure of the recipient State or States to take fully corrective action within a reasonable time, the Board may take one or both of the following measures: direct curtailment or suspension of assistance being provided by the Agency or by a member, and call for the return of materials and equipment made available to the recipient member or group of members. The. Agency may also, in accordance with article XIX, suspend any non-complying member from the exercise of the privileges and rights of membership.

Third, Sec. 669 of the Foreign Assistance Act of 1961, as amended in 1976, would preclude provision of economic assistance, military or security supporting assistance or grant military education and training, or military credits or [commercial] guarantees to any country which

> "(A) delivers nuclear reprocessing or enrichment equipment, materials, or technology to any other country; or
>
> "(B) receives such equipment, materials or technology from any other country;
>
> unless before such delivery--
>
> "(i) the supplying country and receiving country have reached agreement to place all such equipment, materials, and technology, upon delivery, under multilateral auspices and management when available; and
>
> "(ii) the recipient country has entered into an agreement with the International Atomic Energy Agency to place all such equipment, materials, technology, and all nuclear fuel and facilities in such country under the safeguards system of such Agency.

(Within this section, however, provision also is made for Presidential waiver with subsequent Congressional oversight under certain conditions.)

Finally, possible proliferation sanctions, extending beyond termination of nuclear assistance, also were alluded to within former President Ford's October 28th nuclear policy statement. He warned:

> --I serve notice today that the United States will, at a minimum, respond to violation by any nation of any safeguards agreement to which we are a party with an immediate cutoff of our supply of nuclear fuel and cooperation to that nation.
>
> We would consider further steps, not necessarily confined to the area of nuclear cooperation, against the violator nation. Nor will our actions be limited to violations of agreements in which we are directly involved. In the event of material violation of any safeguards agreement, particularly agreements with the IAEA, we will initiate immediate consultations with all interested nations to determine appropriate action.
>
> Universal recognition of the total unacceptability of the abrogation or violation of any nonproliferation agreements is one of the most important steps which can be taken to prevent further proliferation. We invite all concerned governments to affirm publicly that they will regard nuclear wrongdoing as an intolerable violation of acceptable norms of international behavior, which would set in motion strong and immediate countermeasures.

That is, varied references to potential proliferation sanctions already exist within key non-proliferation agreements and policy statements. Further future explicit development of sanctions strategy, should it occur, would be able to build upon these prior initiatives. Whether to move further in that direction depends partly upon the importance of those purposes that might be served by threatening or actually imposing sanctions.

Purposes of Sanctions

One obvious purpose of threatening to impose or imposing sanctions would be to influence directly the policies of the specific prospective proliferator itself. The threat of sanctions, for example, could be used to convince a country that had begun clandestinely to reprocess small quantities of diverted material to cease doing so. Or, their credible threat might help to deter such clandestine violations in the first place. Broadly put, the threat and prospect of sanctions could reinforce perceived proliferation constraints, increasing the likelihood that prospective proliferators would continue to conclude that the costs of "going nuclear" outweighed the benefits.

A second purpose of imposing sanctions would be to influence onlookers' perceptions of the constraints upon and costs of "going nuclear." In the absence of an effective response to the first safeguards agreement violation, for example, other potential proliferators could revise upward, perhaps significantly, estimates of their "freedom of action." But a strong response probably would make such onlookers think again about the costs of "going nuclear." Though not often noted, this "demonstration effect" may be as important a reason for carrying out the threat to impose sanctions as the more direct effect on the particular proliferators.

A third purpose of invoking sanctions, now specifically for a safeguards agreement violation, would be to diminish erosion of the safeguards system's effectiveness. If unopposed, a safeguards violation could seriously weaken IAEA organizational morale. The inspectors might

take their responsibilities less seriously and no longer be as ready to risk questioning ambiguous activities. Further, without the prospect of support from the major powers, the Board of Governors also might be less willing to find instances of non-compliance even were evidence forwarded to it by the Inspector General.

Finally, in conjunction with other non-proliferation measures, a readiness to threaten and, if necessary, impose sanctions would enhance broader efforts to create an anti-nuclear global climate. By imposing sanctions, the United States and other countries would demonstrate the seriousness of their opposition to widespread nuclear proliferation and their willingness to support that goal by action if needed. Conversely, failure to react strongly to a safeguards violation or other future dramatic proliferation events probably would engender and/or reinforce a belief that widespread proliferation was inevitable. Not only would growth of proliferation momentum hinder efforts to control nuclear exports--why sacrifice commercial advantage to a lost cause?, many suppliers might ask--but it also would augment diffuse pressures for acquiring nuclear weapons--better to "go nuclear" now before potential opponents do, many countries might rationalize.

Thus, readiness to utilize sanctions could serve a variety of non-proliferation purposes. Before turning to a discussion of the possible risks and consequences of threatening or imposing sanctions, however, both the types of activities which might trigger sanctions and the implications for sanctions strategy of the context within which particular activities occurred warrant attention.

Triggering Activities and Contextual Complications

Table 1 on the following page enumerates a range of possible events which might trigger sanctions. These include different types of safeguards agreement violations; violations of Agreements for Cooperation; withdrawal from the NPT; nuclear gray marketeering; and movement, though not in violation of any legal obligation, towards a nuclear weapon capability.

However, the specific context within which any of these events occurred could influence the feasibility and/or desirability of invoking sanctions. Consider the following questions whose answers might vary importantly from one situation to the next: Was there any ambiguity concerning either what actions had been taken by the specific country or whether its actions violated any pre-existing legal obligations? If a violation had occurred, were there any extenuating circumstances? Or was the country a special case, one where the imposition of sanctions appeared impolitic or otherwise inappropriate? Would imposing sanctions entail a serious risk of triggering a counter-reaction, and of what magnitude, by the sanctioned country or otherwise endanger important foreign policy interests? Would other countries support an American response, or would they stand aside, or even rally to the support of the sanctioned party? Or, to take a final illustration, would American domestic public opinion and political forces support or merely accept the imposition of sanctions, or perhaps so oppose them and/or so qualify their application in the specific case as to vitiate their impact?

Table 1

POSSIBLE TRIGGERING ACTIVITIES

1. SAFEGUARDS AGREEMENT VIOLATION OR VIOLATION OF AGREEMENT FOR COOPERATION

   A. DIVERSION OF MATERIAL
   B. SEPARATION OF PLUTONIUM
   C. FABRICATION OF A NUCLEAR DEVICE OR ITS CRITICAL COMPONENTS
   D. TESTING OF A NUCLEAR DEVICE
   E. REPLICATION OF TECHNOLOGY
   F. EXPORT OF REPLICATED TECHNOLOGY
   G. DENIAL OF INSPECTION ACCESS
   H. TAMPERING WITH INSPECTION EQUIPMENT

2. WITHDRAWAL FROM NPT

3* GRAY MARKETEERING

   A. TRANSFER OF MATERIALS OR TECHNOLOGY
   B, JOINT PRODUCTION
   C. TRANSFER OF HUMAN RESOURCES

4. MOVEMENT TO NUCLEAR WEAPON CAPABILITY (WITHOUT LEGAL VIOLATIONS)

   A. CREATION OF INDIGENOUS OPTION
   B, COVERT PREPARATIONS FOR TESTING
   C. TESTING OF NUCLEAR WEAPON (QUA PNE?)

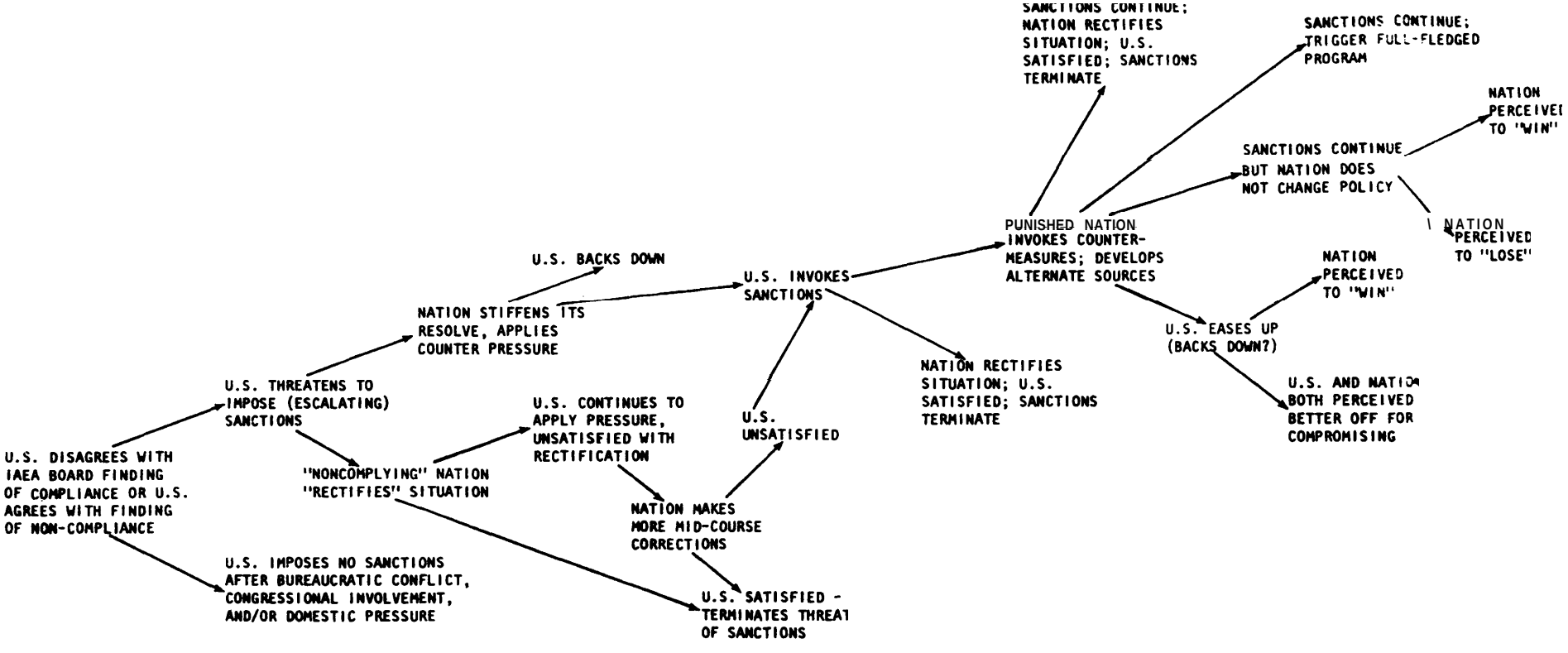
Other questions designed to focus attention upon the peculiarities of particular contexts for threat or imposition of sanctions could be posed. They all suggest that under some conditions there may be compelling reasons not to threaten or apply sanctions. In specific contexts either may appear inappropriate, overly costly, or both. If so, any sanctions strategy may have to permit some degree of flexibility. This need to build flexibility into sanctions strategy becomes even more evident when the varied risks and consequences of invoking sanctions are examined in greater detail.

Risks and Consequences of Threatening and Imposing Sanctions

Turning to the possible consequences of threatening to and/or actually imposing sanctions, the following chart (Table 2) provides a useful starting point. From the vantage point of the United States, it depicts the key decisions that would be involved following an alleged safeguards agreement violation and the major potential alternative outcomes. For ease of discussion, it begins at the point where the United States would be confronted by either an IAEA Board of Governors' finding of non-compliance or one of compliance with which it strongly disagrees. Comparable decision points and alternative possible outcomes would be involved in similar cases beginning from a finding of non-compliance by another supplier nation, an American finding of an Agreement for Cooperation violation, evidence of gray marketeering on the part of some country, an NPT withdrawal, or other triggering activities. The most important possibilities suggested by the chart warrant brief elaboration.

Table 2

ILLUSTRATIVE SANCTION DECISION TREE U.S. BRANCH



First, confronted by an action possibly warranting sanctions, the United States might either simply not impose sanctions or first threaten their imposition and then back down. Among the factors possibly productive of such non-action might be: bureaucratic disagreement about the wisdom of applying sanctions, perhaps threatening other foreign policy goals, in that case; domestic political pressures; fear of reprisal; and/or the lack of suitable levers. As already suggested above, however, the consequences of failure to act could be serious; at the very least, other countries' concern that sanctions would be imposed upon them in similar situations probably would decrease. In particular, if the United States had first threatened to impose sanctions but then backed down, its future threats would be markedly less credible. In addition, many might question the seriousness of American opposition to more widespread proliferation.

Secondly, sanctions could be imposed but their subject might not modify its policy or activities. Not only would such a locally ineffective recourse to sanctions leave the initial country's activities unaffected but, here, too, onlookers might be more prompted to conclude that they, too, had very little to fear. Much would depend upon their particular degree of vulnerability and upon whether American readiness to invoke sanctions, though unsuccessful locally, still would convey a similar future readiness. On that, while granting the importance of local success or failure in influencing onlookers, it may be that for sanctions' further credibility, success need not be total. For example, cessation of clandestine reprocessing though not the return of previously reprocessed material might suffice to deter others.

An additional possible risk is that imposition of sanctions in response to a minor violation, e.g., covert reprocessing of small quantities of plutonium, if it did not produce a cessation of the proscribed activity, actually might trigger a decision to launch a full-fledged nuclear-weapon program. That is, once a country had paid sanctions' political and economic price for a lesser proliferation action, it could decide that the cost had been borne and was bearable, so that it might as well go ahead and acquire the political and military benefits of "going nuclear"

Fourth, threat or imposition of sanctions also entails the risk that the sanctioned nation would threaten or adopt counter-measures painful to the United States, and to its coalition partners in the case of multilateral sanctions. Such retaliatory action might range from using economic counter-leverage--e.g., refusal to repay foreign debts, seizure of foreign investment, or an embargo on key exports such as oil--to engaging in disruptive nuclear export practices--e.g., gray market transfer of nuclear materials, human resources, or technology. Not only might such retaliation hurt the sanctioner, but, as for example with gray marketeering or non-payment of debts, it could provide a source of replacement revenue to aid the sanctioned state.

Each of the preceding potential consequences has emphasized the risks of a sanctions strategy. Nonetheless, as indicated by the chart, a fifth possible outcome is that of successful use of the threat or imposition of sanctions to strengthen proliferation constraints. The sanctioned country could rectify its activities and move to comply with the behavior sought. Or, even though it did not alter its policies,

onlookers still might be impressed by the costs imposed--ones that they, too, could suffer-and by the demonstration of readiness to impose sanctions, both leading them to reassess upward their perception of the constraints upon "going nuclear." Or, at the very least, the costs of non-action in terms of onlookers' perceptions of their freedom of action might be avoided.

However, to insure restored compliance, more than simply the availability of leverage would be needed. Successful use of threatened or imposed sanctions to compel a change of policy also may require certain preconditions. For example, what the desired outcome is following sanctions should be conveyed clearly. That is, what specific actions would terminate sanctions must be stated. For example, in the case of covert reprocessing in violation of an Agreement of Cooperation, the price of revoking sanctions could be cessation of the activity, surrender of the material, and thorough on-site inspection to ensure compliance: the sanctioned country should know specifically which is necessary. Or, following a nuclear test, perhaps qua PNE, the threat of sanctions might be 1 inked to the non-occurrence of a second test. More broadly, if sanctions or their prior threat are to be used successfully not only to deter onlookers but to influence the policies of the sanctioned party, non-proliferation forces and potential proliferators need to have clearly in mind what would either result in the actual imposition of sanctions or their termination once implemented.

Two other possible preconditions for effective use of sanctions should be mentioned. On the one hand, to the extent that the threat of sanctions can be invoked before a possible violation has preceded very

far and before the benefits of violation have begun to accrue, the likelihood of success appears greater. Timely warning, therefore, provides a needed support for sanctions posture. On the other hand, the success of sanctions in terms of their impact upon onlookers may be partly related to perceptions of their legitimacy. The need to legitimate sanctions points to the role of an effective international body such as the IAEA for authorizing sanctions; it also points to the desirability of a careful declaratory policy making clear what may happen in the event of a legal obligation's violation or some other proliferatory action so that action does not appear capricious.

It has to be granted, nonetheless, that the past record of sanctions' threat or imposition has not been one of marked success. Canada's recent termination of nuclear assistance to India did not slow greatly India's nuclear program; nor did Canada's threatened termination of nuclear assistance to Pakistan unless it withdrew its request to purchase a French reprocessing plant produce the desired Pakistani response. Further, United Nations' economic sanctions against Rhodesia have been relatively ineffective in promoting black majority rule: many countries continued to trade with Rhodesia out of need for her products and markets, while Rhodesian economic adaptation, spurred by such outside pressure, produced increased rates of growth, averaging 10 percent, over the last decade. Similar lack of effectiveness characterized use of economic sanctions against Mussolini's Italy by the League of Nations in 1935.

But to extrapolate from the past ineffectiveness of economic sanctions to future sanctions' ineffectiveness may be inappropriate.

Instead, detailed assessment of the degree of existing leverage over specific prospective proliferators is needed. Further, it has to be asked whether fewer countries would have to cooperate now to put together an effective multilateral-sanctions coalition. As proposed below, on both counts--the availability of levers and the size of the coalition necessary for effective multilateral sanctions--the prospect of successful recourse to sanctions or their threat appears significantly greater than in the past.

The preceding discussion of possible consequences, as well as the earlier one of contextual factors, suggests that an overall sanctions strategy would have to minimize the potential negative consequences of sanctions while maximizing their prospective direct and indirect non-proliferation effects. Both action and inaction have their costs and risks. The next section tentatively proposes one such strategy, while also enumerating a range of particular sanctions that could be employed within its basic framework.

Sanctions: Strategy and Levers

One possible American sanctions strategy would distinguish two postures: one threatening automatic imposition of sanctions where a clear violation of a legal obligation was involved; a second designed to create a strong presumption that sanctions might be imposed even following more ambiguous violations or in the event of other proliferatory activities. Such a distinction, providing for a degree of flexibility in the application of sanctions, would constitute a suitable balancing of the potential benefits and risks of sanctions.

On the one hand, as already argued, failure to respond strongly following violation of a legal obligation would have serious adverse effects upon non-proliferation efforts. In this case, the risks of inaction are likely, therefore, to outweigh those of action. This is recognized by the rigid threat of automatic sanctions following violations of legal obligations. On the other hand, the presumptive sanctions posture, while emphasizing that more ambiguous activities and not necessarily illegal proliferatory actions could trigger sanctions, acknowledges that in some cases the costs and risks of taking action may be too high and that flexibility may be desirable. Combining suitable declaratory policy and actual decisions, such a posture would convey to any prospective proliferator the need to take seriously the risk of a strong American response--possibly supported by like-minded nations--to future proliferatory activities.

Within the framework of automatic and presumptive sanctions, a broad set of levers might be utilized. Some of these levers already have been suggested by the initial review of the current status of sanctions. More completely, a list of potential sanctions would include the following:

1. termination of nuclear assistance and exports of nuclear fuel and technology by the United States alone or in cooperation with other nuclear suppliers;
2. delaying or cutting off American Ex-Im Bank loans;
3. delaying or withholding of American economic assistance;
4. American-supported multilateral delaying or withholding of economic assistance;

5. delaying or blocking access to World Bank loans, entailing multi-nation action by a small coalition using their weighted voting power;
6. imposition of a multilateral trade embargo;
7. American refusal to continue supplying late-model conventional arms and associated military training assistance;
8. American withdrawal of a prior security guarantee;
9. redefinition of the coverage of a pre-existing American security guarantee to preclude response should a third party attack the guaranteed country's nuclear-weapon facilities;
10. American expulsion of a country's (engineering) students, termination of landing rights for its airline, prohibition of tourism to and from it, and severance of communications; and
11. a ban on private investment within the country in question.

Given the existence of a broad range of potential levers, what can be said about the relative deterrent impact of each? A more detailed analysis than can be included in this report has indicated that different prospective proliferators are more vulnerable to some levers than to others. Thus, it is not useful to compare the relative deterrent effect, for example, of nuclear-assistance related sanctions to economic assistance sanctions in the abstract. Deterrent impact varies from case to case. At the same time, what does stand out in detailed analyses is the extent to which nearly all prospective near-term proliferators would be vulnerable to one or more of these levers.

This may be illustrated in various ways. Some countries, for example, are planning to depend heavily (40-50 percent of mid- to late-1980s

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* President McNamara's policy is not to bring loans to a vote when 40 percent of the weighted votes are opposed. The United States plus two or three other countries such as Great Britain, Canada, West Germany, Japan, and the Netherlands would control that 40 percent.

projected capacity) upon nuclear power as a source of electricity. Termination of supplies of nuclear fuels and associated materials would seriously affect such countries. For others, foreign economic assistance, including World Bank assistance, provides a significant percentage (more than 25 percent) of yearly capital inflows. Or, even acknowledging that trade can be redirected over time, there are countries for which foreign trade constitutes a very high percentage of GNP (more than 50 percent) and whose current trading patterns entail heavy dependence upon only two or three key trading partners, including the United States. Similarly, for various countries confronting security threats, continued access to supplies of American conventional arms and/or the continuing protection of the American security umbrella can be endangered only at great risk.

But, it may be asked, are such indicators of theoretical vulnerability adequate measures of the potential deterrent effectiveness of sanctions? Several recently reported events, if true, suggest that where such vulnerabilities have been present non-proliferation forces have been able to use the risk of sanctions to further non-proliferation objectives. According to published reports, American pressure was influential in South Korea's decision to forego acquisition of a plutonium reprocessing plant and perhaps in producing clarification of recent rumors about clandestine reprocessing in Taiwan. And, notwithstanding the limited Canadian success vis-a-vis the nuclear programs of India and Pakistan, a Canadian warning that it might reassess its long-term contracts to supply Japan with uranium may have been a factor in that country's decision to ratify the NPT.

To sum up, a range of levers for use within an overall sanctions strategy entailing both automatic and presumptive sanctions exists.

And, depending upon the prospective proliferator in question, a significant degree of vulnerability to one or more of these levers is likely to be present.

The Role of Sanctions

By way of conclusion, two further points about the role of sanctions in non-proliferation strategy should be made explicitly. On the one hand, sanctions are only one of several possible means of reinforcing or increasing proliferation constraints. More importantly, should pressures to acquire nuclear weapons become sufficiently intense--e.g., because a country's political independence or even national survival was seen to be at stake--the prospect of sanctions would be unlikely to prevent a decision to "go nuclear." Measures for defusing proliferation pressures, therefore, remain vital. As with other efforts to increase constraints, e.g., by more tightly controlling nuclear exports, sanctions may be a necessary but not sufficient anti-proliferation tactic.

On the other hand, if the United States and other nations are going to impose sanctions, the legitimacy of doing so would appear to depend partly upon the extent to which they assume responsibility for defusing those proliferation pressures. To illustrate, in the case of countries closely tied to the United States, the counterpart of using leverage to influence their security policies may be a continued American readiness to preserve existing alliance connections. That counterpart in its various manifestations also needs to be borne in mind when thinking about the role of sanctions in non-proliferation strategy.

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o. Treaty of Rome, Chapter VII, Articles 77-85

P. EURATOM, General Budget for Expenditures Related to Safeguards (1977)

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ANNEX A

SAFEGUARDS RELATED ARTICLES FROM THE STATUTE OF INTERNATIONAL ATOMIC ENERGY AGENCY AS AMENDED UP TO JUNE, 1973

THE STATUTE OF THE INTERNATIONAL ATOMIC ENERGY AGENCY
AS AMENDED UP TO JUNE, 1973

ARTICLE II

Objectives

The Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose.

The Safeguards functions are defined in the Statute under Articles 111, A5 and B2 which provide that:

IAEA and International Safeguards-IV.

ARTICLE III

Functions

A. The Agency is authorized:

5* To establish and administer safeguards designed to ensure that special fissionable and other materials, services, equipment, facilities, and information made available by the Agency or at his request or under its supervision or ***control*** are not used in such a way as to further any military purpose; and to apply safeguards, at the request of the parties, to any bilateral or multilateral arrangement, or at the request of a State, to any of that Sate's activities in the field of atomic energy,

and

B. In carrying out its functions, the Agency shall:

2. Establish control over the use of special fissionable materials received by the Agency, in order to ensure that these materials are used only for peaceful purposes.

ARTICLE XI

Agency Projects

F. Upon approving a project, the Agency shall enter into an agreement with the member or group of members submitting the project, which agreement shall:

4. Include undertakings by the member or group of members submitting the project: (a) that the assistance provided shall not be used in such a way as to further any military purpose; and (b) that the project shall be subject to the safeguards provided for in article X11, the relevant safeguards being specified in the agreement.

ARTICLE XII

Agency Safeguards

A. With respect to any Agency project, or other arrangement where the Agency is requested by the parties concerned to apply safeguards, the Agency shall have the following rights and responsibilities to the extent relevant to the project or arrangement:

1. To examine the design of specialized equipment and facilities, including nuclear reactors, and to approve it only from the view-point of assuring that it will not further any military purpose, that it complies with applicable health and safety standards, and that it will permit effective application of the safeguards provided for in this article;

2. To require the observance of any health and safety measures prescribed by the Agency;

3. To require the maintenance and production of operating records to assist in ensuring accountability for source and special fissionable materials used or produced in the project or arrangement:

4. To call for and receive progress reports;

5. To approve the means to be used for the chemical processing of irradiated materials solely to ensure that this chemical processing will not lend itself to diversion of materials for military purposes and will comply with applicable health and safety standards; to require that special fissionable materials recovered or produced as a by-product be used for peaceful purposes under continuing Agency safeguards for research or in reactors, existing or under construction, specified by the member or members concerned; and to require deposit with the Agency of any

excess of any special fissionable materials recovered or produced as a by-product over what is needed for the above- stated uses in order to prevent stockpiling of these materials, provided that thereafter at the request of the member or members concerned special fissionable materials so deposited with the Agency shall be returned promptly to the member or members concerned for use under the same provisions as stated above:

6. To send into the territory of the recipient State or States inspectors, designated by the Agency after consultation with the State or States concerned, who shall have access at all times to all places and data and to any person who by reason of his occupation deals with materials, equipment, or facilities which are required by this Statute to be safeguarded, as necessary to account for source and special fissionable materials supplied and fissionable products and to determine whether there is compliance with the undertaking against use in furtherance of any military purpose referred to in sub-paragraph F-4 of article XI, with the health and safety measures referred to in sub-paragraph A-2 of this article, and with any other conditions prescribed in the agreement between the Agency and the State or States concerned. Inspectors designated by the Agency shall be accompanied by representatives of the authorities of the State concerned, if that State so requests, provided that the inspectors shall not thereby be delayed or otherwise impeded in the exercise of their functions:

7. In the event of non-compliance and failure by the recipient State or States to take requested corrective steps within a reasonable time, to suspend or terminate assistance and withdraw any materials and equipment made available by the Agency or a member in furtherance of the project.

B. The Agency shall, as necessary, establish a staff of inspectors. The staff of inspectors shall have the responsibility of examining all operations conducted by the Agency itself to determine whether the Agency is complying with the health and safety measures prescribed by it for application to projects subject to its approval, supervision or control, and whether the Agency is taking adequate measures to prevent the source and special fissionable materials in its custody or used or produced in its own operations from being used in furtherance of any military purpose. The Agency shall take remedial action forthwith to correct any non-compliance or failure to take adequate measures.

c. The staff of inspectors shall also have the responsibility of obtaining and verifying the accounting referred to in sub-paragraph A-6 of this article and of determining whether there is compliance with the undertaking referred to in sub-paragraph F-4 of article XI, with *the* measures referred to in sub-paragraph A-2 of this article, and with all other conditions of the project prescribed in the agreement between the Agency and the State or States concerned. The inspectors shall report any non-compliance to the Director General who shall thereupon transmit the report to the Board of Governors. The Board shall call upon the recipient State or States to remedy forthwith any non-compliance which it finds to have occurred. The Board shall report the non-compliance to all members and to the Security Council and General Assembly of the United Nations. In the event of failure of the recipient State or States to take fully corrective action with a reasonable time, the Board may take one or both of the following measures: direct curtailment or suspension of assistance being provided by the Agency or by a member, and call for the return of materials and equipment made available to the recipient member or group of members. The Agency may also, in accordance with article XIX, suspend any non-complying member from the exercise of the privileges and rights of membership.

ANNEX B

LIST OF THE MEMBER STATES (IAEA)

APPENDIX VI

IAEA MEMBER NATIONS
JUNE 22, 1976

Afghanistan
Albania*
Algeria*
Argentina*
Australia
Austria
Bangladesh*
Belgium
Bolivia
Brazil*
Bulgaria
Burma*
Belorussian Soviet Socialist Republic*
Cambodia (Khmer Republic)
Cameroon
Canada
Chile*
Colombia
Costa Rica
Cuba*
Cyprus
Czechoslovak Socialist Republic
Denmark
Dominican Republic
Ecuador
Egypt, Arab Republic of
El Salvador
Ethiopia
Finland
France*
Gabon
German Democratic Republic
Germany, Federal Republic of
Ghana
Greece
Guatemala
Haiti
Holy See (Vatican City)
Hungary
Iceland
India*
Indonesia
Iran
Iraq
Ireland
Israel*
Italy
Ivory Coast
Jamaica
Japan
Jordan
Kenya
Korea, Democratic People's Republic of*
Korea, Republic of
Kuwait
Lebanon
Liberia
Libyan Arab Republic
Liechtenstein*
Luxembourg
Madagascar
Malaysia
Mali
Mauritius
Mexico
Monaco*
Mongolia
Morocco
Netherlands
New Zealand
Niger*
Nigeria
Norway
Pakistan*
Panama
Paraguay
Peru
Philippines
Poland
Portugal*
Qatar*

Romania
Saudi Arabia*
Senegal
Sierra Leone
Singapore
South Africa*
Spain*
Sri Lanka
Sudan
Sweden
Switzerland
Syrian Arab Republic
Thailand
Tunisia
Turkey
Uganda*
Ukranian Soviet Socialist Republic*
Union of Soviet Socialist Republics
United Arab Emirates*
United Kingdom of Great Britain and Northern Ireland
United Republic of Tanzania*
United States of America
Uruguay
Venezuela
Vietnam
Yugoslavia
Zaire, Republic of
Zambia*

* Member nations that are not party to NPT.

ANNEX C

DETAILED COSTS OF THE SAFEGUARDS PROGRAM

COSTS OF THE PROGRAMME

Summary by items of expenditure: Table N.1

Item of expenditure	1973 Actual obligations	1976 Adjusted budget	Increase or (decrease) from 1976			1977 Estimate	1978 Preliminary estimate
			Price	Programme	Total		
Salaries and wages							
Established posts	2 375 032	3 158 000	280 000	277 000	557 000	3 715 000	4 382 000
Consultants	39 873	21 000	600	20 400	21 000	42 000	47 000
Overtime	205	1 000	-	1 000	1 000	2 000	2 000
Temporary assistance	862	-	-	5 000	5 000	5 000	5 000
Sub-total	2 415 972	3 180000	280600	303 400	584000	3 764000	4 436 000
Common staff costs	709 100	917000	113500	86 500	200000	1 117000	1 316 000
Travel	350 638	410000	17400	87 600	105000	515000	610000
Meetings							
Conferences, symposia, seminars	36 659	-		30 000	30000	30000	55000
Technical committees. advisory groups	37 342	67000	3500	13 500	17000	84000	76 000
Representation and hospitality	9 323	8000	1 000	2 000	3000	11 000	12000
Scientific and technical contracts	143 902	490 000	10000	(14 000)	(4 000)	486000	550000
Scientific supplies and equipment	406 217	510000	41000	27 000	68000	578 000	543 000
Common services, supplies and equipment	44 226			-	-		
Transfer of costs:							
Linguistic services	122 072	75000	8000	73 000	81000	156000	148 000
Printing and publishing services	57 541	69000	6000	5 000	11 000	80000	90000
Data processing services	151 175	125000	13000	262 000	275000	400000	500000
Laboratory services	381 466	496000	72000	56 000	128000	624000	663000
Other: Legal services	96 000	96000	10000		10000	106000	112000
TOTAL	4961 633	6443000	576000 8.9%	932000 14.5%	1508000 23.4%	7 951 000	9 111 000

SUMMARY OF MANPOWER

Table N. 2

Grade of post	Number of established posts					
	1975 Adjusted	1976	1976 Adjusted	Change	1977	1978 Preliminary estimate
IG	1	1	1		1	1
D	2	3	3	1	4	4
P-5	19	24	24	4	28	30
P-4	33	36	36	5	41	48
P-3	35	33	33	1	34	36
P-2	11	5	5	(2)	3	3
Sub-total	101	102	102	9	111	122
GS	35	36	36	14	50	57
TOTAL	136	138	138	23	161	179

ANNEX D

AGENCY INFORMATION CIRCULAR/26, 30 **MARCH, 1961 (REF:** INFCIRC/26, 30 MARCH, 1961, IAEA, VIENNA, AUSTRIA

International Atomic Energy Agency

INFCIRC/26
30 March 1961
GENERAL Distr.
Original: ENGLISH

THE AGENCY'S SAFEGUARDS

On 31 January 1961 the Board of Governors approved the Agency's safeguards system, which is set forth in this document for the information **of all** Members.

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I. INTRODUCTION

1. Under Article III. A. 5 of the Statute the Agency is authorized

> "to establish and administer safeguards designed to ensure that special fissionable and other materials, services, equipment, facilities, and information made available by the Agency or at its request or under its supervision or control are not used in such a way as to further any military purpose; and to apply safeguards, at the request of the parties, to any bilateral or multilateral arrangement, or, at the request of a State, to any of that State's activities in the field of atomic energy."

2. The principles and procedures established for the information and appropriate guidance of Member States as well as for the guidance of the Board itself in the administration of safeguards by the Agency, are based on the pertinent provisions of the Statute and enable:

(a) A State or group of States applying for assistance by or through the Agency to consider in advance the nature of the safeguards that the Agency would attach;

(b) The parties to a bilateral or multilateral arrangement, or a State, to determine how Agency safeguards might be applied to their activities if they so request; and

(c) The Board to determine readily what safeguards should be attached to Agency projects or applied to arrangements that the Agency has been requested to safeguard, and embodied in the relevant agreements.

3. Agency safeguards will be applied to materials and facilities voluntarily placed under Agency safeguards by a State or States. Where two or more States request the Agency to administer the safeguards provisions of an agreement between those States, the Agency will apply those provisions provided that they are consistent with the procedures laid down in this document. The administration of safeguards by the Agency under this paragraph shall be governed by an agreement pursuant to the Statute between the Agency and the State or States concerned which shall be made for a specified period.

4. This document specifies:

(a) The principles that are to be followed by the Agency in determining the safeguards that are to be attached and applied to various types of assistance, and

(b) The procedures to implement these principles.

The safeguards procedures cover the anticipated requirements by the Agency in the immediate future and relate only to research, test and power reactors with less than 100 megawatts thermal output, to the source and special fissionable material used and produced in these reactors and to small research and development facilities. Procedures covering other types of nuclear facilities will be developed as the probable need for them becomes evident. In regard to produced material, the safeguards provided for in this document relate only to first generation produced material.

5. The principles and procedures for the attachment and application of safeguards by the Agency which are set forth hereafter shall be subject to a general review after two years, in the light of the actual experience gained by the Agency as well as of the technological development which has taken place.

Ix. DEFINITIONS

6. "Agency" means the International Atomic Energy Agency.

7. “Statute" means the Statute of the Agency.

8. "Board" means the Board of Governors of the Agency.

9. "Director General" means the Director General of the Agency.

31 Agency safeguards will be applied to specialized equipment and non-nuclear materials to which Agency safeguards are attached and to facilities [3] incorporating these items.

IV. ATTACHMENT AND TERMINATION OF AGENCY SAFEGUARDS

A. Attachment to nuclear materials

32. (a) Agency safeguards will be attached to source material supplied by the Agency and to special fissionable material produced in or by the use of such material, except when the quantity of PN source material in a State, including the material supplied by the Agency, does not exceed:

(i) In the case of natural uranium or depleted uranium with a uranium-235 content of 0.5 per cent or greater - 10 metric tons;

(ii) In the case of depleted uranium with a uranium-235 content of less than 0. 5 per cent - 20 metric tons;

(iii) In the case of thorium - 20 metric tons.

(b) Agency safeguards will be attached to special fissionable material supplied by the Agency and to special fissionable material produced in or by the use of such material, except when the quantity of PN special fissionable material in a State, including the material supplied by the Agency, does not exceed 200 grams of plutonium, uranium -“23 3 or fully enriched uranium or its equivalent in the case of partially enriched uranium. [4] Safeguards will be applied in a nominal marine r when the amount of PN special fissionable material in a State does not exceed 1 000 grams [4] .

33. Agency safeguards will be attached to special fissionable material produced in a principal nuclear facility to which Agency safeguards are attached.

34. Agency safeguards will be attached to nuclear material processed or used in a principal nuclear facility to which Agency safeguards are attached.

35. Agency safeguards will be attached to all special fissionable material produced in a reactor to which Agency safeguards are not attached but which contains nuclear material to which Agency safeguards are attached, if such material permits the reactor to operate at , more than 200 per cent of the power at which it could operate without such material.

B. Attachment to facilities, equipment and non-nuclear material

36. Agency safeguards will be attached to principal nuclear facilities supplied or, in the opinion of the Board, substantially assisted by the Agency. Reactors which, after an inspection at initial criticality, are assessed by the Board to have a maximum calculated power for continuous operation of less than 3 thermal megawatts shall be exempted from such attachment provided that the total such power of reactors thus exempted in any State may not exceed 6 thermal megawatts.

37. Agency safeguards will be attached to specialized equipment and non-nuclear material supplied by the Agency, which in the opinion of the Board could substantially assist a principal nuclear facility, other than a reactor with a maximum calculated power for continuous operation of less than 3 thermal megawatts, or could in other ways further a military purpose, even when such specialized equipment or non-nuclear material is not in a principal nuclear facility. The Board may from time to time designate certain specific specialized equipment and non-nuclear material as being items which would be considered capable of substantially assisting a principal nuclear facility or in other ways of furthering a military purpose.

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[4] Equivalent amounts can be determined ‘from the equation in the Appendix. The equivalent amounts of plutonium and uranium-233 are the same as for fully enriched uranium.

10. "Nuclear material" means any source and/or special fissionable material as defined in Article XX of the Statute.

11. "Enrichment" means the percentage by weight of the isotope uranium-235 in the total uranium present.

12. "Depleted uranium" means uranium in which the percentage by weight of the isotope uranium -235 in the total uranium present is less than that occurring in natural uranium.

13. "Reactor" means any device that can be operated so as to maintain a controlled, self-sustaining fission chain reaction.

14. "Reactor facility" means a reactor including appurtenant facilities such as fuel storage or cooling facilities or other portions of the plant in which nuclear materials are handled or used.

15. "Principal nuclear facility" means reactor facilities, plants for processing special fissionable or irradiated source material, plants for separating the isotopes of uranium or isotopes of plutonium and such other facilities or plants which may be designated by the Board.

16. "Supplied or processed by the Agency" means supplied or processed by the Agency directly, or supplied or processed with the assistance of the Agency when, in the opinion of the Board, that assistance is of a substantial nature.

17. "Diversion" means the use by a recipient State of fissionable or other materials, facilities or equipment supplied by the Agency so as to further any military purpose or in violation of any other condition prescribed in the agreement between the Agency and the State concerning the use of such materials, facilities or equipment.

18. "Agency safeguards" means the measures pursuant to the Statute to prevent loss or diversion of materials, specialized equipment or principal nuclear facilities.

19. "Attachment" of safeguards" means the requirement to apply appropriate safeguard procedures.

20. "Application of safeguards" to materials or facilities means the implementation of appropriate safeguards procedures.

21. "PN [1] material" and "PN facility" mean materials and facilities:

(a) Supplied by the Agency or to which Agency safeguards are otherwise attached;

(b) Placed under Agency safeguards by agreement with the State or States concerned;

(c) Allocated by a State for peaceful purposes exclusively, provided the State concerned voluntarily sends the Agency notification thereof in connection with Agency safeguards; or

(d) Supplied from a source external to a State under an agreement that they shall not be used to further a military purpose or otherwise safeguarded in that State by other organizations or States, provided that all parties concerned shall have voluntarily notified the Agency in connection with Agency safeguards of the material or facilities supplied or otherwise safeguarded in the State so that the Agency can take account thereof.

[1] This abbreviation means "peaceful nuclear".

31 Agency safeguards will be applied to specialized equipment and non-nuclear materials to which Agency safeguards are attached and to facilities 3] incorporating these items.

Iv. ATTACHMENT AND TERMINATION OF AGENCY SAFEGUARDS

A. Attachment to nuclear materials

32. (a) Agency safeguards will be attached to source material supplied by the Agency and to special fissionable material produced in or by the use of such material, except when the quantity of PN source material in a State, including the material supplied by the Agency, does not exceed:

(i) In the case of natural uranium or depleted uranium with a uranium-235 content of O. 5 per cent or greater - 10 metric tons;

(ii) In the case of depleted uranium with a uranium-235 content of less than O. 5 per cent -20 metric tons;

(iii) In the case of thorium - 20 metric tons.

(b) Agency safeguards will be attached to special fissionable material supplied by the Agency and to special fissionable material produced in or by the use of such material, except when the quantity of PN special fissionable material in a State, including the material supplied by the Agency, does not exceed 200 grams of plutonium, uranium-"233 or fully enriched uranium or its equivalent in the case of partially enriched uranium. [4] Safeguards will be applied in a nominal manner when the amount of PN special fissionable material in a State does not exceed 1 000 grams [4] .

33. Agency safeguards will be attached to special fissionable material produced in a principal nuclear facility to which Agency safeguards are attached.

34. Agency safeguards will be attached to nuclear material processed or used in a principal nuclear facility to which Agency safeguards are attached.

35. Agency safeguards will be attached to all special fissionable material produced in a reactor to which Agency safeguards are not attached but which contains nuclear material to which Agency safeguards are attached, if such material permits the reactor to operate at more than 200 per cent of the power at which it could operate without such material.

B. Attachment to facilities, equipment and non-nuclear material

36. Agency safeguards will be attached to principal nuclear facilities supplied or, in the opinion of the Board, substantially assisted by the Agency. Reactors which, after an inspection at initial criticality, are assessed by the Board to have a maximum calculated power for continuous operation of less than 3 thermal megawatts shall be exempted from such attachment provided that the total such power of reactors thus exempted in any State may not exceed 6 thermal megawatts.

37. Agency safeguards will be attached to specialized equipment and non-nuclear material supplied by the Agency, which in the opinion of the Board could substantially assist a principal nuclear facility, other than a reactor with a maximum calculated power for continuous operation of less than 3 thermal megawatts, or could in other ways further a military purpose, even when such specialized equipment or non-nuclear material is not in a principal nuclear facility. The Board may from time to time designate certain specific specialized equipment and non-nuclear material as being items which would be considered capable of substantially assisting a principal nuclear facility or in other ways of furthering a military purpose.

[4] Equivalent amounts can be determined from the equation in the Appendix. The equivalent amounts of plutonium and uranium-233 are the same as for fully enriched uranium.

31 Agency safeguards will be applied to specialized equipment and non-nuclear materials to which Agency safeguards are attached and to facilities [3] incorporating these items.

IV. ATTACHMENT AND TERMINATION OF AGENCY SAFEGUARDS

A. Attachment to nuclear materials

32. (a) Agency safeguards will be attached to source material supplied by the Agency and to special fissionable material produced in or by the use of such material, except when the quantity of PN source material in a State, including the material supplied by the Agency, does not exceed:

(i) In the case of natural uranium or depleted uranium with a uranium-235 content of 0. 5 per cent or greater - 10 metric tons;

(ii) In the case of depleted uranium with a uranium-235 content of less than 0. 5 per cent - 20 metric tons;

(iii) In the case of thorium - 20 metric tons.

(b) Agency safeguards will be attached to special fissionable material supplied by the Agency and to special fissionable material produced in or by the use of such material, except when the quantity of PN special fissionable material in a State, including the material supplied by the Agency, does not exceed 200 grams of plutonium, uranium -233 or fully enriched uranium or its equivalent in the case of partially enriched uranium. [4] Safeguards will be applied in a nominal manner when the amount of PN special fissionable material in a State does not exceed 1 000 grams [4] .

33. Agency safeguards will be attached to special fissionable material produced in a principal nuclear facility to which Agency safeguards are attached.

34. Agency safeguards will be attached to nuclear material processed or used in a principal nuclear facility to which Agency safeguards are attached.

35. Agency safeguards will be attached to all special fissionable material produced in a reactor to which Agency safeguards are not attached but which contains nuclear material to which Agency safeguards are attached, if such material permits the reactor to operate at more than 200 per cent of the power at which it could operate without such material.

B. Attachment to facilities, equipment and non-nuclear material

36. Agency safeguards will be attached to principal nuclear facilities supplied or, in the opinion of the Board, substantially assisted by the Agency. Reactors which, after an inspection at initial criticality, are assessed by the Board to have a maximum calculated power for continuous operation of less than 3 thermal megawatts shall be exempted from such attachment provided that the total such power of reactors thus exempted in any State may not exceed 6 thermal megawatts.

37. Agency safeguards will be attached to specialized equipment and non-nuclear material supplied by the Agency, which in the opinion of the Board could substantially assist a principal nuclear facility, other than a reactor with a maximum calculated power for continuous operation of less than 3 thermal megawatts, or could in other ways further a military purpose, even when such specialized equipment or non-nuclear material is not in a principal nuclear facility. The Board may from time to time designate certain specific specialized equipment and non-nuclear material as being items which would be considered capable of substantially assisting a principal nuclear facility or in other ways of furthering a military purpose.

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[4] Equivalent amounts can be determined from the equation in the Appendix. The equivalent amounts of plutonium and uranium-233 are the same as for fully enriched uranium.

facilities already approved under the project agreement, the State will advise the Agency accordingly and submit such designs for examination and approval together with any information that the Agency may request.

43. The Agency shall make its decision about approval of these designs as expeditiously as possible after the submission of the information by the State.

(c) Procedure for agreement of the records system

44. The State shall agree with the Agency a plan for the system of records for each facility and material to which Agency safeguards are to be applied. A draft of this plan shall be submitted by the State in sufficient time to permit review by the Agency and adoption by the State of an agreed system before the records need to be u seal. Any changes in this plan shall similarly be agreed with the Agency.

45. The records shal1 include operating records for nuclear facilities, as well as accounting records of material and equipment, to which Agency safeguards are applied.

46, All records shall be retained for at least two years.

(d) Procedure for submission of reports

(i) General considerations

47. The State shall agree with the Agency a plan for the system of reports for each facility and material to which Agency safeguards are to be applied. A draft of this plan shall be submitted by the State in sufficient time to permit review by the Agency and adoption by the State of the agreed plan before the first report is required to be submitted.

(ii) Routine reports

48. The State shall submit the following routine reports to the Agency:

(a) Operating reports showing the use that has been made of the facility and the material in the facility since the last report and as far as possible the program of work which is going to be carried out in the facility and with the material; and

(b) Accounting reports showing the. receipt, issue and location of the material to which Agency safeguards are applied.

49* The State shall submit the first routine report at the time of the first operation of the facility under Agency safeguards or at the time when material to which Agency safeguards are attached is first received at the facility.

50. At the request of the Agency the State shall submit amplifications or elucidations of routine reports referred to in paragraph 48 above, in the event of unusual circumstances as determined by the Agency.

(iii) Special reports

51. The State shall notify the Agency within forty-eight hours by the most expeditious means available:

(a) If any unusual incident occurs, involving an actual or potential loss, destruction or damage of any facility or material to which Agency safeguards are applied; or

(b) If materia1 is lost or unaccounted for in quantities that exceed those normal operating losses or unaccounted-for quantities that are accepted by the Agency to be characteristic of the facility involved.

52. The State shall submit to the Agency a report at least two weeks before:

(a) Any proposed transfer or other transaction that will result in a change in the quantity of materials to which Agency safeguards are applied in the State, or a significant change in any facility or complex of facilities considered as a unit for this purpose by agreement with the Agency; and

(b) Any proposed major change in the planned future program as reported in the routine reports.

53. The State shall submit any additional special reports requested by the Agency concerning matters referred to in paragraphs 51 and 52 above.

(e) Procedure for inspections

(i) Routine inspections

54. The Agency may make routine inspections of the facility and material to which Agency safeguards are applied, beginning at a time specified in the project agreement.

55. Inspections will include the examination of the facility to ensure that it is constructed in accordance with the approved design, and the testing of any equipment or instruments that are to be used to measure material in the facility to which Agency safeguards are to be applied. The testing of instruments and equipment shall be carried out only to the extent necessary to test their proper functioning, without reference to their design.

56. Routine inspections after the facility is in operation shall normally include:

(a) Examination of the facility and/or material to which Agency safeguards **are** applied;

(b) Audit of reports and records;

(c) Verification of the amounts of material to which Agency safeguards are applied, by physical inspection, measurement and sampling; and

(d) Examination and testing of the measurement instruments,

57. If the Agency considers that all the routine inspections that are authorized are not required, fewer inspections may be carried out.

(ii) Special inspections

58. If an examination of the special reports made under paragraphs 51 and 52 above indicates the need for a special inspection, the Agency is entitled to carry out such an inspection, to investigate the occurrence.

59. In the event of unforeseen circumstances requiring immediate action, a special inspection may be made provided that a report shall be made to the Board on the circumstances leading to such inspection.

(f) Nominal safeguards

60. If the quantities of PN special fissionable material in the State are such that material supplied by the Agency qualifies for the application of safeguards in a nominal reamer as specified in sub-paragraph 32(b) above the following shall apply:

(a) Only one routine report shall be required each year regarding the material and the facilities which are processing, using, or storing such material;

(b) No routine inspections shall be carried out; and

(c) Special reports will be submitted and special inspections performed as necessary.

B. Additional procedures for application to reactor facilities

(a) Introduction

61. The following additional provisions apply to reactor facilities. In the present procedures only reactors below 100 thermal megawatts are considered.

(b) Frequency of routine reports

62. The frequency of routine reports for a facility shall normally be twice a year. The actual frequency for a given facility shall be determined in relation to the frequency of inspection of that facility.

(c) Frequency of routine inspections

63. Routine inspections shall be made to each facility to which safeguards are applied except those subject only to nominal safeguards.

64. The number of inspections will be kept to a minimum consistent with the effective application of safeguards.

65. The frequency of inspection of a reactor facility shall take into account the following considerations:

(a) The possession by the State or States of an irradiated fuel reprocessing facility;

(b) The nature of the reactor facility;

(c) The nature of the nuclear material used or produced in the reactor facility; and

(d) The amount of nuclear material used or produced in the reactor facility.

In the light of these considerations, routine inspections shall be conducted at such a frequency that in the interval between inspections the total possible error in the measurement of the quantity of nuclear material used or produced by the reactor facility [5] cannot amount to more than O. 2 kilograms of plutonium, uranium-233 or fully enriched uranium-235 or their equivalents. The maximum frequency of routine inspections for a reactor facility shall be as shown in the table below. The first column of this table indicates the annual usage [6] or the maximum potential production of plutonium, uranium-233 or uranium-235 expressed in equivalent kilograms, and the second column indicates the corresponding inspection frequencies.

[51 For the purposes of this document "the total possible error in the measurement of the quantity of nuclear material used or produced by the reactor facility" shall mean one standard deviation of the measurement.

[6] Annual usage is the equivalent yearly throughput or inventory, whichever is larger, and "equivalent" is used in the sense in which it is used in paragraph 32 above and in the Appendix.

Frequency of routine inspections 7]

Annual usage or maximum potential production of Pu, uranium-233 or uranium-235 (Equivalent kilograms)	Maximum number of routine inspections per year
From 0.2 to 1	None (Nominal safeguards)
More than 1 up to 5	1
More than 5 up to 10	2
More than 10 up to 15	3
More than 15 up to 20	4
More than 20 up to 25	5
More than 25 up to 30	6

The appropriate number of routine inspections will be stated in each project agreement and provision made therein for changes in case of changed conditions.

c . Additional procedures for application to research and development facilities other than reactor facilities

66. In this paragraph the only research and development facilities that are provided for are those in a State which possesses PN special fissionable material in quantities that qualify, in accordance with sub-paragraph 32(b) above, for the application of safeguards in a nominal manner. For such facilities the application shall be limited to that shown in paragraph 60 above.

[7] Examples of the application of the principle illustrated in the above table are given in the following table; they are calculated on the basis of typical operating conditions at the reactor facility:

Illustrative frequencies of routine inspection

Type of reactor facility	Design power	Enrichment of fuel (per cent)	Number of routine inspections per year
Homogeneous research	50 KW	20	None, subject to the provisions of paragraphs 32 and 36 above
Heavy water research	3 MW	Natural	
Pool research	1 MW	20	
Pool research	2 MW	90	
Graphite moderated research	4 MW	Natural	1
Test or large research	30 MW	20	2
Pressurized water **power**	40 MWT	**4**	2
Boiling water power	58 MWT	4.2	2
Test or large research	20 MW	90	4
Graphite moderated power	100 MWT	Natural	6

APPENDIX

Equivalent amounts of enriched uranium

1. The amount of partially enriched uranium that is equivalent to 200 grams of fully enriched uranium, is given by the equation:

$$\text{Amount of uranium in kilograms} = \frac{0.2}{\frac{(\text{Enrichment})^2}{(100)^2}}$$

2. The amount of partially enriched uranium equivalent to x kilograms of fully enriched uranium can be determined by substituting x for the figure O. 2 in the equation in paragraph 1 above.

ANNEX E

INFORMATION CIRCULAR 66/REV.2

THE AGENCY'S SAFEGUARDS SYSTEM (1965, AS PROVISIONALLY EXTENDED IN 1966 AND 1968)

16 September 1968

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, AUSTRIA

SELECTED PARAGRAPHS

I. GENERAL CONSIDERATIONS

B. GENERAL PRINCIPLES OF THE AGENCY's SAFEGUARDS

9. Bearing in mind Article II of the Statute, the Agency shall implement safeguards in a manner designed to avoid hampering a State's economic or technological development.

10. The safeguards procedures set forth in this document shall be implemented in a manner designed to be consistent with prudent management practices required for the economic and safe conduct of nuclear activities,

11. In no case shall the Agency request a State to stop the construction or operation of any principal nuclear facility to which the Agency's safeguards procedures extend, except by explicit decision of the Board.

12. The State or States concerned and the Director General shall hold consultations regarding the application of the present document.

13. In implementing safeguards, the Agency shall take every precaution to protect commercial and industrial secrets. No member of the Agency's staff shall disclose, except to the Director General and to such other members of the staff as the Director General may authorize to have such information by reason of their official duties in connection with safeguards. any commercial or industrial secret or any other confidential information

coming to his knowledge by reason of the implementation of safeguards by the Agency.

4. The Agency shall not publish or communicate to any State, organization or person any information obtained by it in connection with the implementation of safeguards,except that:

(a) Specific **information relating to such implementation in a State** may be given **to** the Board **and to such Agency staff members as require such knowledge by reason of their official duties** in connection with safeguards, but only to the extent necessary for the Agency to fulfill its safeguards responsibilities.

(b) Summarized lists of items being safeguarded by **the** Agency may be published upon **decision of the Board and**

‘(c) Additional **information may be published** upon decision of the Board and if all States directly concerned agree.”

PRINCIPLES OF IMPLEMENTATION

16. In the light of Article XII.A.5 of the Statute, it is desirable that safeguards agreements should provide for the continuation of safeguards, subject to the provisions of this document, with respect to produced special fissionable material and to **any materials substituted therefor.**

17. The principal factors to be considered by the Board in determining the relevance of particular provisions of this document to various types of materials and facilities shall be the form, scope and amount of the assistance supplied, the character of each individual project and the degree to which such assistance could further any military purpose. The related safeguards agreement shall take account of all pertinent circumstances at the time of its conclusion.'"

III. SAFEGUARDS PROCEDURES

A. GENERAL PROCEDURES
INTRODUCTION

29 The safeguards procedures set forth below shall be followed, as far as relevant, with respect to safeguarded nuclear materials, whether they are being produced, processed or used in any principal nuclear facility or are *outside* any such facility. These procedures also extend to facilities containing or to contain such materials, including principal nuclear facilities to which the criteria in paragraph 19(d) apply."

30. The Agency shall review the design of principal nuclear facilities, for the sole purpose of satisfying itself that a facility will permit the effective application of safeguards.

31. The design review of a principal. nuclear facility shall take place at as early a stage as possible. In particular, such review shall be carried out in the case of:

"(a) An Agency project, before the project is approved;

"(b) A bilateral or multilateral arrangement under which the responsibility for administering safeguards is to be transferred to the Agency, or an activity unilaterally submitted by a State, before the Agency assumes safeguards responsibilities with respect to the facility:

"(c) A transfer of safeguarded nuclear material to a principal nuclear facility whose design has not previously been reviewed, before such transfer takes place and

"(d) A significant modification of a principal nuclear facility whose design has previously been reviewed, before such modification is undertaken.

32. To enable the Agency to perform the required design review, the State shall submit to it relevant design information sufficient for the purpose, including information on such basic characteristics of the principal nuclear facility as may bear on the Agency's safeguards procedures. The Agency shall require only the minimum amount of information and data consistent with carrying out its responsibility under this section. It shall complete the review promptly after the submission of this information by the State and shall notify the latter of its conclusions without delay."

ANNEX F

A LIST OF THE AGREEMENTS PROVIDING FOR SAFEGUARDS OTHER THAN THOSE IN CONNECTION WITH NPT. APPROVED BY THE BOARD OF GOVERNORS AS OF DECEMBER 1975

Ref. : The Annual Report for 1975, GC(xx)565, International Atomic Energy Agency, Vienna, Austria, July, 1976

Agreements providing for safeguards other than those
in connection with NPT,
approved by the Board as of 31 December 1975

Party(ies)[a]	Subject	Entry into force	INFCIRC
Project Agreements			
Argentina	Siemens SUR-100	13 Mar 1970	143
	RAEP Reactor	2 Dec 1964	62
Chile	Herald Reactor	19 Dec 1969	137
Finland[b]	FiR-1 Reactor	30 Dec 1960	24
	FINN sub-critical assembly	30 Jul 1963	53
Greece[b]	GRR-1 Reactor	1 Mar 1972	163
Indonesia	Additional core-load for Triga Reactor	19 Dec 1969	136
Iran[b]	UTRR Reactor	10 May 1967	97
Japan	JRR-3	24 Mar 1959	3
Mexico[b]	TRIGA-III Reactor	18 Dec 1963	52
	Siemens SUR-100	21 Dec 1971	162
	Laguna Verde Nuclear Power Plant	12 Feb 1974	203
Pakistan	PRR Reactor	5 Mar 1962	34
	Booster rods for KANUPP	17 Jun 1968	116
Philippines[b]	PRR-1 Reactor	28 Sep 1966	88
Republic of South Viet-Nam	VNR-1 Reactor	16 Oct 1967	106
Romania[b]	TRIGA Reactor	30 Mar 1973	206
Spain	Coral I Reactor	23 Jun 1967	99
Turkey	Sub-critical assembly	17 May 1974	212
Uruguay	URR Reactor	24 Sep 1965	67
Venezuela	RV-1 Reactor	7 Nov 1975	
Yugoslavia[b]	TRIGA-II	4 Oct 1961	32
	KRSKO Nulcear Power Plant	14 Jun 1974	213
Zaire[b]	TRICO Reactor	27 Jun 1962	37
Transfer Agreements (Agreements for transfer of safeguards under bilateral co-operation agreements between the indicated Parties)			
Argentina/United States of America		25 Jul 1969	130
Australia[b]/United States of America		26 Sep 1966	91
Australia[b]/Japan		28 Jul 1972	170/Corr. 1
Austria[b]/United States of America		24 Jan 1970	152
Brazil/United States of America		20 Sep 1972	110/Mod. 1
Canada/Japan		12 Nov 1969	85/Mod. 1
Canada[b]/India		30 Sep 1971	211
China, Republic of/United States of America		6 Dec 1971	158
Colombia/United States of America		9 Dec 1970	144
France/Japan		22 Sep 1972	171
France/Korea, Republic of[b]		22 Sep 1975	
India/United States of America		27 Jan 1971	154
Indonesia/United States of America		6 Dec 1967	109
Iran[b]/United States of America		20 Aug 1969	127
Israel/United States of America		4 Apr 1975	

Party(ies)[a]	Subject	Entry into force?	INFCIRC
Japan / United States of America		10 Jul 1968	119
Japan/ United Kingdom		15 Oct 1968	125
Korea, Republic of/ United States of America		19 Mar 1973	11 l/Mod. 1
Pakistan/Canada		17 Oct 1969	135
Philippines[b]/United States of America		19 Jul 1968	120
Portugal/United States of America		19 Jul 1969	131
South Africa/United States of America		28 Jun 1974	98
Spain/ United States of America		28 Jun 1974	92
Sweden[b]/United States of America		1 Mar 1972	165
Switzerland/United States of America		28 Feb 1972	161
Turkey /United States of America		5 Jun 1969	123
Venezuela/United States of America		27 Mar 1968	122
Unilateral submissions			
Argentina	Atucha Power Reactor Facility	3 Oct 1972	168
	Nuclear material	23 Oct 1973	202
	Embalse Power Reactor Facility	6 Dec 1974	224
Chile	Nuclear material	31 Dec 1974	
China, Republic of	Taiwan Research Reactor Facility	13 Oct 1969	133
Mexico[b]	All nuclear activities	6 Sep 1968	118
Panama[c]	All nuclear activities		
Spain	Nuclear material	19 Nov 1974	218
	Nuclear material	18 Jun 1975	221
Switzerland	Nuclear material		
United Kingdom	Certain nuclear activities	14 Dec 1972	175

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

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

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

ANNEX G

A LIST OF BILATERAL AGREEMENTS FOR COOPERATION

APPENDIX III

AGREEMENTS FOR **COOPERATION IN THE CIVIL USES OF** ATOMIC ENERGY

(AS OF NOVEMBER 1, 1975)

A. Bilateral with individual countries:

Country	Scope	Effective date	Termination date
Argentina	Research and power	July 25, 1969	July 24, 1999
Australia	Research and power	May 28, 1957	May 27, 1997
Austria	Research and power	Jan. 24, 1970	Jan. 23, 2014
Brazil	Research and power	Sept. 20, 1972	Sept. 19, 2002
Canada	Research and power	July 21, 1955	July 13, 1980
China, Rep. of	Research and power	June 22, 1972	June 21,2014
Colombia	Research	Mar. 29, 1963	Mar. 28, 1977
Finland	Research and power	July 7, 1970	July 6, 2000
Greece (note a)	Research	Aug. 4, 1955	Aug. 3, 1974
India	Power (Tarapur)	Oct. 25, 1963	Oct. 24, 1993
Indonesia	Research	Sept. 21, 1960	Sept. 20, 1980
Iran	Research	Apr. 27, 1959	Apr. 26, 1979
Ireland	Research	July 9, 1958	July 8, 1978
Israel	Research	July 12, 1955	Apr.- 11, 1977
Italy	Research and power	Apr. 15, 1958	Apr. 14, 1978
Japan	Research and power	July 10, 1968	July 9, 2003
Korea	Research and power	Mar. 19, 1973	Mar. 18, 2014
Norway	Research and power	June 8, 1967	June 7, 1997
Philippines	Research and power	July 19, 1968	July 18, 1998
Portugal	Research and power	June 26, 1974	June 25, 2014
South Africa	Research and power	Aug. 22, 1957	Aug. 21, 2007
Spain	Research and power	June 28, 1974	June 27, 2014
Sweden	Research and power	Sept. 15, 1966	Sept. 14, 1996
Switzerland	Research and power	Aug. 8, 1966	Aug. 7, 1996
Thailand	Research and power	June 27, 1974	June 26, 2014
Turkey	Research	June 10, 1955	June 9, 1981
United Kingdom	Research and power	July 21, 1955	July 20, 1976
United Kingdom	Power	July 15, 1966	July 14, 1976
Venezuela	Research and power	Feb. 9, 1960	Feb. 8, 1980
Vietnam	Research	July 1, 1959	June 30, 1979

~/Superseding research and power agreement in abeyance; U.S. material covered by IAEA (NPT) safeguards.

B. Bilaterals with international organizations

Organization	Scope	Effective date	Termination date
European Atomic Energy Community (EURATOM)	Joint nuclear power program	Feb. 18, 1959	Dec. 31, 1985
EURATOM	Additional agreement to joint nuclear power program	July 25, 1960	Dec. 31, 1995
International Atomic Energy Agency (IAEA)	supply of materials, etc.	Aug. 7, 1959	Aug. 6, 2014

ANNEX H

A LIST OF U. 5..-IAEA TRILATERAL SAFEGUARDS AGREEMENT

APPENDIX III

U.S.-IAEA TRILATERAL SAFEGUARDS AGREEMENTS FOR APPLICATION OF IAEA SAFEGUARDS TO U.S.-SUPPLIED MATERIALS

Third party	Effective date	Termination date (note a)
Argentina	7/25/69	AC
Australia (suspended 7/10/74) (note b)	9/26/66	AC
Austria (suspended 7/23/72) (note b)	1/24/70	AC
Brazil (amended 9/20/72)	10/31/68	AC
China, Republic of	12/ 6/71	AC
Colombia	12/ 9/70	AC
Denmark (suspended 3/1/72) (note b)	2/29/68	AC
India	1/27/71	AC
Indonesia	12/ 6/67	AC
Iran (suspended 5/15/74) (note b	8/20/69	AC
Israel	6/15/66	AC
Japan	7/10/68	Ac
Korea (amended 3/19/73)	1/ 5/68	AC
Philippine (suspended 10/16/74) (note b)	7/19/68	AC
Portugal	7/19/69	AC
South Africa (amended 6/28/74)	7/26/67	AC
Spain (amended 6/28/74)	12/ 9/66	AC
Sweden	3/ 1/72	AC
Switzerland	2/18/72	AC
Turkey	6/ 5/69	AC
Venezuela	3/27/68	AC

~/AC indicates termination on same date *as* agreement for co-operation.

~/Suspended in view of NPT safeguards agreements with IAEA.

ANNEX I

INFORMATION CIRCULAR /153

THE STRUCTURE AND CONTENTS OF AGREEMENTS BETWEEN THE AGENCY AND STATES REQUIRED IN CONNECTION WITH THE TREATY ON NON-PROLIFERATION OF NUCLEAR WEAPONS

IAEA

SELECTED PARAGRAPHS

"1. **The Agreement should contain, in accordance with Article III.1 of the Treaty on the Non-Proliferation of Nuclear Weapons**[1], **an undertaking by the State to accept safeguards, in accordance with the terms of the Agreement, on all source or special fissionable material in all peaceful nuclear activities** within its territory, under its jurisdiction or carried out under its control anywhere, for the exclusive purpose of verifying that such material is not diverted to nuclear weapons or other nuclear explosive devices."

IMPLEMENTATION OF SAFEGUARDS

4. (Add texts of ¶H)

4. **The Agreement should provide that** safeguards shall be implemented in a manner designed:

(a) To avoid hampering the economic and technological development of the State or international cooperation in the field of peaceful nuclear **activities, including international exchange of** ***nuclear material***[2];

(b) To avoid undue interference in the State's peaceful nuclear activities, and in particular in the operation of facilities; and

(c) To be consistent with prudent management practices required for the economic and safe conduct of nuclear activities.

"5. ..the Agency shall take every precaution to protect commercial and industrial secrets and other confidential information coming to its knowledge in the implementation of the Agreement. The Agency shall not publish or communicate to any State, organization or person any information obtained by it in connection with the inplementation of the Agreement, except that specific information relating to such implementation in the State may be given to the Board of Governors and to such Agency staff members as require such knowledge by reason of their official duties in connection with safeguards, but only to the extent necessary for the Agency to fulfill its responsibilities in implementing the Agreement. Summarized information on nuclear material being safeguarded by the Agency under the Agreement may be published upon decision of the Board if the States directly concerned agree."

6. The Agreement should provide that in implementing safeguards pursuant thereto the Agency shall take full account of technological developments in the field of safeguards, and shall make every effort to ensure optimum cost-effectiveness and the application of the principle of safeguarding effectively the flow of nuclear material subject to safeguards under the Agreement by use of instruments and other techniques at certain strategic points to the extent that present or future technology permits. In order to ensure optimum cost-effectiveness, use should be made, for example, of such means as:

"(a) Containment as a means of defining material balance areas for accounting purposes:

"(b) Statistical techniques and random sampling in evaluating the flow of nuclear material: and

"(c) Concentration of verification procedures on those stages in the nuclear fuel cycle involving the production. processing, use or storage of nuclear material from which nuclear weapons or other nuclear explosive devices could readily be made, and minimization of verification procedures in respect of other nuclear material, on condition that this does not hamper the Agency in applying safeguards under the Agreement."'

"7. The Agreement should provide that the State shall establish and maintain a system of accounting for and control of all nuclear material subject to safeguards under the Agreement, and that such safeguards shall be applied in such a manner as to enable the Agency to verify, in ascertaining that there has been no diversion of nuclear material from peaceful uses to nuclear weapons or other nuclear explosive devices, findings of the State's system. The Agency's verification shall include, inter alia. independent measurements and observations conducted by the Agency in accordance with the procedures specified in Part II below. The Agency, in its verification, shall take due account of the technical effectiveness of the State's system,"

"8. The Agreement should provide that to ensure the effective implementation of safeguards thereunder the Agency shall be provided, in accordance with the provisions set out in Part II below with information concerning nuclear material subject to safeguards under the Agreement and the features of facilities relevant to safeguarding such material. The Agency shall require only the minimum amount of information and data consistent with carrying out its responsibilities under the Agreement. Information pertaining to facilities shall be the minimum necessary for safeguarding nuclear material subject to safeguards under the Agreement. in examining design information, the Agency shall, at the request of the State, be prepared to examine on premises of the State design information which the State regards as being of particular sensitivity. Such information would not have to be physically transmitted to the Agency provided that it remained available for ready further examination by the Agency on premises of the State."

"18. The Agreement should provide that if the Board, upon report of the Director General, decides that an action by the State is essential and urgent in order to ensure verification that nuclear material subject to safeguards under the Agreement is not diverted to nuclear weapons or other nuclear explosive devices the Board shall be able to call upon the State to take the required action without delay, irrespective of whether procedures for the settlement of a dispute have been invoked.

"19. The Agreement should provide that if the Board upon examination of relevant information reported to it by the Director General finds that the Agency is not able to verify that there has been no diversion of nuclear material required to be safeguarded under the Agreement to nuclear weapons or other nuclear explosive devices, it may make the reports provided for in paragraph C of Article XII of the Statute and may also take, where applicable, the other measures provided for in that paragraph. In taking such action the Board shall take account of the degree of assurance provided by the safeguards measures that have been applied and shall afford the State every reasonable opportunity to furnish the Board with any necessary reassurance.

"20. The Agreement should provide that the parties thereto shall, at the request of either, consult about any question arising out of the interpretation or application thereof.

"21. The Agreement should provide that the State shall have the right to request that any question arising out of the interpretation or application thereof be considered by the Board; and that the State shall be invited by the Board to participate in the discussion of any such question by the Board.

"22. The Agreement should provide that any dispute arising out of the interpretation or application thereof except a dispute with regard to a finding by the Board under paragraph 19 above or an action taken by the Board pursuant to such a finding which is not settled by negotiation or another procedure agreed to by the parties should, on the request of either party, be submitted to an arbitrator, and the two arbitrators so designed would elect a third, who would be the Chairman. If, within 30 days of the request for arbitration, either party has not designed an arbitrator, either party to the dispute may request the President of the International Court of Justice to appoint an arbitrator. The same procedure would apply if, within 30 days of the designation or appointment of the second arbitrator, the third arbitrator had not been elected. A majority of the members of the arbitral tribunal would constitute a quorum, and all decisions would require the concurrence of two arbitrators. The arbitral procedure would be fixed by the tribunal. The decision of the tribunal would be binding on both parties.

PART II

OBJECTIVES OF SAFEGUARDS

"28. The Agreement should provide that the objective of safeguards is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection.

"29. To this end the Agreement should provide for the use of material accountancy as a safeguards measure of fundamental importance, with containment and surveillance as important complementary measures.

"30. The Agreement should provide that the technical conclusion of the Agency's verification activities shall he a statement, in respect of each material balance area, of the amount of material unaccounted for over a specific period, giving the limits of accuracy of the amounts stated.'"

DESIGN INFORMATION

General

42. Pursuant to paragraph 8 above, the Agreement should stipulate that design information in respect of existing facilities shall be provided to the Agency during the discussion of the Subsidiary Arrangements, and that the time limits for the provision of such information in respect of new facilities shall be specified in the Subsidiary Arrangements. It should further be stipulated that such information shall be provided as early as possible before nuclear material is introduced into a new facility.

43. The Agreement should specify that the design information in respect of each facility to be made available to the Agency shall include, when applicable:

(a) Identification of the facility, stating its general character, purpose, nominal capacity and geographic location, and the name and address to be used for routine business purposes;

(b) Description of the general arrangement of the facility with reference, to the extent feasible, to the form, location and flow of nuclear material and to the general layout of important items of equipment which use, produce or process nuclear material;

(c) Description of features of the facility relating to material accountancy, containment and surveillance; and

(d) Description of the existing and proposed procedures at the facility for nuclear material accountancy and control, with special reference to material balance areas established by the operator, measurements of flow and procedures for physical inventory taking.

44. The Agreement should further provide that other information relevant to the application of safeguards shall be made available to the Agency in respect of each facility, in particular on organizational responsibility for material accountancy and control. It should also be provided that the State shall make available to the Agency supplementary information on the health and safety procedures which the Agency shall observe and with which the inspectors shall comply at the facility.

45. The Agreement should stipulate that design information in respect of a modification relevant for safeguards purposes shall be provided for examination sufficiently in advance for the safeguards procedures to be adjusted when necessary.

"'46. The Agreement should provide **that the design information made available to the Agency shall be used for the following purposes:**

" (a) To **identify the features of facilities and nuclear material relevant to the application of safeguards to nuclear material in sufficient detail to facilitate verification.**

"(b) To determine material balance areas to be used for Agency accounting purposes and to select those strategic points which are key measurement points and which will be used to determine the nuclear material flows and inventories: in determining such material balance areas the Agency shall, inter alia, use the following criteria;

"(i) The size of the material balance area should be related to the accuracy with which the material balance can be established

"(ii) In determining the material **balance area advantage should be taken of any opportunity to use containment and** Surveillance **to help ensure the completeness of flow** measurements and thereby simplify the application of safeguards and concentrate measurement efforts at key measurement points;

"(iii) A number of material balance areas in use at a facility or at distinct **sites may be-combined** in one **material balance area to be used for Agency accounting**

purposes when the Agency determines that this is consistent with its verification requirements: and

"(iv) If the State so requests, a special material balance area around a process step involving commercially sensitive information may be established*

"(c) To establish the nominal timing and procedures for taking of physical inventory for Agency accounting purposes:

"(d) To establish the records and reports requirements and records evaluation procedures:

"(e) To establish requirements and procedures for verification of the quantity and location of nuclear material and

"(f) To select appropriate combinations of containment and surveillance methods and techniques and the strategic points at which they are to be applied.

"It should further be provided that the results of the examination of the desire information shall be included in the Subsidiary Arrangements."

PURPOSE OF INSPECTIONS

72. The Agreement should provide that the Agency may make routine inspections in order to:

"(a) Verify that reports are consistent with records:

"(b) Verify the location, identify, quantity and composition of all nuclear material subject to safeguards under the Agreement and

"(c) Verify information on the possible causes of material unaccounted for, shipper/receiver differences and uncertainties in the book inventory."

INSPECTIONS
Access for Inspections

"76...(c) For the purposes specified in paragraph 72 above the Agency's inspectors shall have access only to the strategic points specified in the Subsidiary Arrangements and to the records maintained pursuant to paragraphs 51-58; and

"(d)In the event of the State concluding that any unusual circumstances require extended limitations on access by the Agency, the State and the Agency shall promptly make arrangements with a view to enabling the Agency to discharge its safeguards responsibilities in the light of these limitations. The Director General shall report each such arrangement to the Board."

"78. The Agreement should provide that the number, intensity, duration and timing of routine inspections shall be kept to the minimum consistent with the effective implementation of the safeguards procedures set forth therein, and that the Agency shall make the optimum and most economical use of available inspection resources.

"79. The Agreement should provide that in the case of facilities and material balance areas outside facilities with a content or annual throughput, whichever is greater, of nuclear material not exceeding five effective kilograms, routine inspections shall not exceed one per year. For other facilities the number, intensity, duration, timing and mode of inspections shall be determined on the basis that in the maximum or limiting case the inspection regime shall be no more intensive than is necessary and sufficient to maintain continuity of knowledge of the flow and inventory of nuclear material.

"80. The Agreement should provide that the maximum routine inspection effort in respect of facilities with a content or annual throughput of nuclear material exceeding five effective kilograms shall be determined as follows:

"(a) For reactors and sealed stores, the maximum total of routine inspection per year shall be determined by allowing one sixth of a man-year of inspection for each such facility in the State:

"(b) For other facilities involving plutonium of uranium enriched to more than 5%, the maximum total of routine inspection per year shall be determined by allowing for each such facility 30 X /Ė man-days of inspection per year, where .E is the inventory or annual throughput of nuclear material, whichever is greater, expressed in effective kilograms. The maximum established for any such facility shall not however. be less than 1.5 man-years of inspection: and

"(c) For all other facilities, the maximum total of routine inspection per year shall be determined by allowing for each such facility one third of a man-year of inspection plus 0.4 X E man-days of inspection per year, where E is the inventory or annual throughput of nuclear material, Whichever is greater, expressed in effective kilograms.

"The Agreement should further provide that the Agency and the State may agree to amend the maximum figures specified in this paragraph upon determination by the Board that such amendment is reasonable.

"81. Subject to paragraphs 78-80 above the criteria to be used for determining the actual number, intensity, duration, timing and mode of routine inspections of any facility shall include*

'(a) The form of nuclear material, in particular, whether the material is in bulk form or contained in a number of separate items: its chemical composition and, in the case of uranium, whether it is of low or high enrichment: and its accessibility:

'(b) The effectiveness of the State's accounting and control system, including the extent to which the operators of facilities are functionally independent of the State's accounting and control system: the extent to which the measures specified in paragraph 32 above have been implemented by the State: the promptness of reports submitted to the Agency; their consistency with the Agency's independent verification: and the amount and accuracy of the material unaccounted for, as verified by the Agency;

"(c) Characteristics of the State's nuclear fuel cycle, in particular, the number and types of facilities containing nuclear material subject to safeguards, the characteristics of such facilities relevant to safeguards, notably the degree of containment* the extent to which the design of such facilities facilitates verification of the flow and inventory of nuclear material; and the extent to which information from different material balance areas can be correlated

"(d) International interdependence, in particular, the extent to which nuclear **material is received from or sent to other States for use or Processing; any verification activity by the Agency in connection therewith; and the extent to which the State's nuclear activities are interrelated with those of other States: and**

"(e) Technical **developments in** the field of safeguards? including the use of statistical techniques and random sampling in evaluating the flow of nuclear material."

ANNEX J

OUTLINE OF THE SAFEGUARDS TECHNICAL MANUAL

Outline of Safeguards Technical Manual

Part A Safeguards Objectives, Criteria and Requirements

Chapter 1 Objectives

Chapter 2 Description of the nuclear material system

Chapter 3 Criteria

Chapter 4 Requirements

Chapter 5 Diversion hazards

Part B Nuclear Activities and Facilities

Chapter 1 Uranium isotopic enrichment

Chapter 2 Conversion and fuel fabrication

Chapter 3 Reactors

Chapter 4 Irradiated fuel processing

Chapter 5 Scrap processing

Chapter **6 Storages**

Chapter 7 Research and development

Chapter 8 Nuclear material outside facilities

Chapter **9** Transfer of nuclear material

Part C Inspections

Chapter 1 Objectives

Chapter 2 Procedures for verification of flow and inventory

Chapter 3 Inspection of uranium isotopic enrichment facilities

Chapter **4** Inspection of conversion and fuel fabrication facilities

Chapter 5 Inspection of reactors

Chapter **6** Inspection of irradiated fuel processing facilities

Chapter **7** Inspection of scrap processing facilities

Chapter **8** Inspection of storages

Chapter **9** Inspection of research and development facilities

Chapter 10 Inspection of nuclear material outside facilities

Chapter 11 Inspection of nuclear material transfers

Part D Evaluation of the Information

Chapter 1	Objectives
Chapter 2	Evaluation of the information provided by the State
Chapter 3	Evaluation of the information collected in the inspections
Chapter 4	Evaluation of the information provided by the analytical services
Chapter 5	Evaluation of the information provided by the State, inspections and analytical services for an MBA
Chapter 6	Evaluation of the information provided by the State, inspections and analytical services for a group of interrelated MBA's
Chapter 7	Basic design and operational features of the Agency's system for storage, retrieval and processing of the information

Part II Methods and Techniques

Chapter 1	Classification of nuclear materials, measuring conditions, and measurement methods
Chapter 2	Standard reference materials
Chapter 3	Methods for weight and volume measurement
Chapter 4	Methods of sampling
Chapter 5	Analytical methods of measurement of nuclear material
Chapter 6	Methods of non-destructive analysis of nuclear material
Chapter 7	Methods of using isotopic composition
Chapter 8	Measurement accuracy for different combinations of materials, conditions and methods
Chapter. 9	Methods of containment
Chapter 10	Methods of surveillance
Chapter 11	Methods of identification of nuclear materials

Part F Statistical Concepts and Techniques

Chapter 1	Basic concepts
Chapter 2	Random number tables
Chapter 3	Graphical representations
Chapter 4	Estimation of parameters
Chapter 5	Tests of significance
Chapter 6	Paired comparison techniques
Chapter 7	Attribute tests
Chapter 8	Cumulative sum techniques
Chapter 9	Sequential sampling
Chapter 10	Error evaluation

ANNEX K

IAEA SAFEGUARDS TECHNICAL MANUAL
INTRODUCTION
PART A

SAFEGUARDS OBJECTIVES, CRITERIA AND REQUIREMENTS
Section on Significant Quantities

"5. '..3. Significant Quantities

"The expression 'Significant quantities' is understood as quantities of nuclear material which are of importance for the manufacture of nuclear weapons or other nuclear explosive devices. The only guidelines to define the quantities which are of safeguards importance are the quantities of nuclear material required to manufacture a single nuclear explosive or the quantity needed to produce by appropriate conversion the material required to manufacture such an explosive.

"The amounts of material required for the manufacture of one nuclear explosive have been estimated in one study (4) to be 25 kilograms of uranium containing 90 to 95 percent uranium-235 or 8 kilograms of plutonium containing 95 percent plutonium-239. These amounts are related to fast critical masses, and experiments with fast critical assemblies provide information regarding the relative amounts of other isotopes required to manufacture a nuclear explosive. Examples of some bare spherical critical masses are 52 kg of uranium containing 94 percent of the 235 isotope 16.5 kg of uranium containing 98 percent of the 233 isotope: 17 kg of plutonium (95 percent Pu-239 and 4.5% Pu-240) and 19.5 kg of plutonium (76 percent of Pu-239, 20 percent Pu-240) and 3 percent

Pu-241). Measurements of reactivity contributions made in fast critical facilities indicate similar reactivity coefficients for Pu--239 and U-233 and a reactivity coefficient for Pu--240 intermediate between those of Pu-239 and U-235. The critical masses noted above are significantly less when reflecting material is used. For example, the critical spherical mass of 94 percent U-235 is about 18 kg when surrounded by a 7-inch thick reflector of natural uranium and about 26 kg when surrounded by a 1.74-inch thick reflector (5).

"For uranium containing less than 90 to 95 percent U-235 the weight of contained U-235 in a critical mass increases gradually as the enrichment is decreased down to an enrichment of approximately 20 percent, with the specific critical mass weights depending upon the amount and type of reflector material. Below enrichments of about 20 percent the weights of critical masses increase very rapidly with about 680 kg of uranium (100 kg contained U-235) being required for a 'critical mass of 16 percent U-235 with a 3-inch natural uranium reflector (5).

"Based upon the above considerations the quantities of nuclear material required for the manufacture of a single nuclear explosive device, for material types not requiring enrichment or irradiation, are taken by the IAEA to be 8 kg of plutonium for all types of plutonium for which the isotopic concentration of PU-238 does not exceed 80 percent: and for uranium in which the combined weights of the U-233 and U-235 isotopes equal or exceed 20 percent of the total uranium weight, 8 kg of contained U-233 and U-235 when the U-233

isotopic concentration is the larger of the two and 25 kg of contained U-235 when the U-235 isotopic concentration is the larger.

"For uranium containing less than 20 percent concentration of the U-233 and U-235 isotopes and for thorium either isotopic enrichment or irradiation **in a reactor is considered to be required to produce material from which nuclear explosive devices could be manufactured. In general, quantities larger than** 25 kg of contained U-235 by a factor of 2 to 4 would be required to produce the material from which a single nuclear explosive device could be manufactured. For example, to produce by isotopic enrichment 25 kg of uranium of 90% enrichment, assuming a tails assay of 0.003%, would require about 6 tons of natural uranium containing about 43 kg of U-735. If depleted uranium (assay 0.004% were used as feed for isotopic enrichment about 25 tons of feed, containing about 100 kg contained U-235 would be needed to produce 25 kg of 90% enriched uranium. If natural uranium were to be irradiated in a reactor to produce plutonium at a relatively low burn-up level (approximately 600 to 800 megawatt-days/ton of uranium which results typically in about 0.5 kg of plutonium per ton of uranium) about 16 tons of natural uranium containing about 120 kg of U-235 would he needed to produce 8 kg of plutonium.

"These values indicate the order of magnitude of the quantity of material required to manufacture a device. Therefore, in the case of States having a sizable scale nuclear activity, the IAEA would have to conclude on the non-diversion of a very small fraction of the State'; inventory of nuclear **material.**

"5.1.3 Detection Probability and Confidence' Level

"Neither INFCIRC/66/Rev.2 nor INFCIRC/153 mentions the concepts of degree of certitude of detection and degree of certitude of not concluding that a diversion has taken place when it has not. The IAEA interprets that these concepts, which are usually expressed by the statistical terms 'probability of detection' and 'confidence level of detection', are implicit in these two documents.

"Experts **from Member States have recommended that the IAEA use values between 90 and 99% for both. In most cases this will be 95%.**

ANNEX L

THE IAEA ANNUAL REPORT FOR 1975, SECTION ON SAFEGUARDS

General

125. The Review conference of the Parties to the Treaty on the Non - Proliferation of Nuclear Weapons, which met from 5 to 30 May, expressed strong supper t for effective Agency safeguards. The Conference paid special attention to export policies, standard and universal application of the Agency's safeguards, improvement of methods and techniques and safeguards instruments and the physical protection of nuclear material against forcible seizure.

126. The Director General has set up a Standing Advisory Group on safeguards implementation to provide advice on technical aspects of Agency safeguards. The Group held its first meeting in December 1975 and began its examination of verification procedures and safeguards practices.

127. The Board has taken a number of steps to clarify the scope and duration of safeguards agreements concluded outside the framework of NPT and of safeguards requirements in connection with the transfer of scientific and technological information. These steps have been reflected in recent agreements.

128. The Agency has also helped Member States to set up their national systems of accounting for, and control of, nuclear material and has given training to staff who are responsible for submitting accounting information to the Agency under safeguards agreements in connection with NPT.

129. The part of the safeguards information handling system which deals with reports received from States' systems of accounting and control on nuclear material subject to safeguards under NPT, is now handling reports from some States party to NPT and is being tested for the remainder.

130. The Agency convened the third symposium on the safeguarding of nuclear material in October 1975. The symposium reviewed the ''state of the art" in safeguards methods, techniques and instrumentation and it attracted wide participation.

Implementation of Agency safeguards

131. At the end of 1975 the Agency had safeguards agreements in force with 64 States. The Board had also approved agreements with 17 further States, which are awaiting entry into force.

132. Of the agreements in force 44 were with States party to NPT and 23 of these States "have significant nuclear activities (see Table 8 at the end of this section). In addition, safeguards were being applied in 20 States under 11 project agreements, 21 safeguards transfer agreements and eight unilateral submission agreements (see Table 9).

133. During 1975 the Board approved:

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

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

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

(d) A Safeguards Agreement between the Agency, France and the Republic of Korea;

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

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

.134. The negotiation of agreements to implement the offers of the United Kingdom and the United States in connection with the application of safeguards in those two States had entered the final stage.

1350 The Agency's records showed the following quantities of nuclear material to be under Agency safeguards:

	1970	1971	1972	1973	1974	1975
Plutonium (kg)						
(a) Contained in irradiated fuels						6661
(b) In other forms						2374
(C) Total	770	1 726	2 900	4730	6300	9035
Enriched uranium						
(a) Total element (tonnes)	243	522	1 178	1 865	2305	3 096
(b) Fissile content (tonnes)	6.1	11.2	26.0	43.0	53,0	66.7
Source material (tonnes)	1 146	1 200	2 145	3370	3910	4440

136. During 1975 the Agency carried out 515 inspections in 39 States (216 in connection with NPT), compared with 474 inspections (165 in connection with NPT) in 38 States during the preceding year. Of the 515 inspections, 214 were made of power plants, 104 of bulk fuel plants and 197 of other facilities including research reactors.

137. Inspectors are being trained in the use of recently introduced non-destructive analytical instruments and techniques and this has improved further the quality of verification.

138. By the end of 1975 the compilation of individual I 'Safeguards Implementation Practices" enabling the Agency to achieve consistency of inspection procedure in respect of all facilities where nuclear material was being safeguarded, was well underway. [10]

1390 A list of nuclear installations under Agency safeguards or containing material safeguarded under arrangements approved by the Board is given in Table 10. The breakdown on 31 December 1975 compared to 30 June of the same year is as follows:

[10] See **also** document GC(XIX)544, para. 141.

Facilities	NPT		Non-NPT	
	30 June	31 December	30 June	31 December
Nuclear power stations	18	18	25	~[11]
Research reactors and critical facilities	47	47	56	56
Conversion plants, fabrication plants and fuel reprocessing plants	7	7	22	22
Other separate accountability areas[12]	47	47	93	93

Safeguards development

140. An Advisory Group on States Systems of Accounting for and Control of Nuclear Material met at Brno, Czechoslovakia, in July 1975 and extended the work of the panel held in Tokyo in November 1973 [13].

141. An advisory group which met in April 1975 prepared a revised set of recommendations [14] to help Member States to minimize the risk of sabotage in nuclear facilities or theft of nuclear material. The Secretariat is studying the legal instruments that might be appropriate for ensuring physical protection of nuclear material, particularly when it is transported internationally.

142. The construction of the Safeguards Analytical Laboratory at Seibersdorf was completed in November 1975 and work on certain categories of samples was expected to begin early in the new year.

143. In March 1975 an advisory group helped to draw up guidelines for the development of safeguards techniques during the next five years. During the year, containment and surveillance systems have been further refined, particular attention being paid to optical devices, instruments to monitor the movement of material in nuclear plants and techniques for sealing. There has also been further progress in techniques for non-destructive measurement of the fissile material content of fuel assemblies and irradiated fuel.

144. The cost of research and technical contracts awarded during 1975 amounted to $699790, of which 15% was contributed by the Agency and the remainder by the institutes or Governments concerned. A coordinated research programme for setting up a bank of correlated isotopic data was started with Member States and EURATOM. The data bank will be used to develop isotopic correlation techniques and to apply them as a means of verification of burn-up production of fissile material and reprocessing input analysis.

145. Volume E of the Agency's safeguards technical manual was released for production in 1975.

[11] The basis for this number has been changed since 1975; it now relates only to nuclear power stations that have been subject to inspection during the year under review, whether or not they have started operation.

[12] Contiguous minor locations where very small amounts of nuclear materials are kept have been grouped together.

[13] See document GC(XVIII)/525, para.165.

(14) Document INFCIRC/225.

Table 8

Situation on 31 December 1975 with respect to the signature of, ratification of, or accession to, NPT by non-nuclear-weapon States, and the conclusion of safeguards agreements between the Agency and these States in connection with NPT

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

(1)	(2)	(3)
Lebanon	15 July 1970	In force: 5 March 1973
Lesotho	20 May 1970	In force: 12 June 1973
Liberia	5 March 1970	
Libyan Arab Republic	26 May 1975	
Luxembourg	2 May 1975	Signed: 5 April 1973
Madagascar	8 October 1970	In force: 14 June 1973
Malaysia	5 March 1970	In force: 29 February 1972
Maldives	7 April 1970	Under negotiation
Mali	5 March 1970	Under negotiation
Malta	6 February 1970	Under negotiation
Mauritius	28 April 1969	In force: 31 January 1973
Mexico	21 January 1969	In force: 14 September 1973
Mongolia	14 May 1969	In force: 5 September 1972
Morocco	30 November 1970	In force: 18 February 1975
Nepal	5 January 1970	In force: 22 June 1972
Netherlands b/	2 May 1975	Signed: 5 April 1973
New Zealand	10 September 1969	In force: 29 February 1972
Nicaragua	6 March 1973	Signed: 28 February 1975
Nigeria	27 September 1968	Under negotiation
Norway	5 February 1969	In force: 1 March 1972
Panama		
Paraguay	4 February 1970	
Peru	3 March 1970	Under negotiation
Philippines	5 October 1972	In force: 16 October 1974
Poland	12 June 1969	In force: 11 October 1972
Republic of South Viet-Nam	10 September 1971	In force: 9 January 1974
Romania	4 February 1970	In force: 27 October 1972
Rwanda	20 May 1975	
San Marino	10 August 1970	Under negotiation
Senegal	17 December 1970	
Sierra Leone	26 February 1975	Under negotiation
Singapore		Under negotiation
Somalia	5 March 1970	Under negotiation
Sri Lanka		
Sudan	31 October 1973	Signed: 26 February 1975
Surinam b/		In force: 5 June 1975
Swaziland	11 December 1969	In force: 28 July 1975
Sweden	9 January 1970	In force: 14 April 1975
Switzerland		Under negotiation
Syrian Arab Republic	24 September 1969	
Thailand	7 December 1972	In force: 16 May 1974
Togo	26 February 1970	
Tonga	7 July 1971	Approved by the Board
Trinidad and Tobago		
Tunisia	26 February 1970	Under negotiation
Turkey		
United Republic of Cameroon	8 January 1969	
Upper Volta	3 March 1970	
Uruguay	31 August 1970	Signed: 24 September 1971
Venezuela	26 September 1975	
Western Samoa	18 March 1975	
Yemen Arab Republic		
Yugoslavia	3 March 1970	In force: 28 December 1973
Zaire	4 August 1970	In force: 9 November 1972

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

b/ Agreements have also been concluded in respect of the Netherlands Antilles and Surinam, under NPT and Additional Protocol I to the Treaty for the Prohibition of Nuclear Weapons in Latin America. These agreements entered into force on 5 June 1975. By letter of 29 November 1975, the Prime Minister of Surinam, which attained independence on 25 November 1975, informed the Secretary-General of the United Nations that his Government acknowledged that treaty rights and obligations of the Government of the Kingdom of the Netherlands in respect of Surinam were succeeded to by the Republic of Surinam upon independence and that it was desired that it be presumed that each treaty has been legally succeeded to by the Republic of Surinam and that action be based upon this presumption until a decision was reached that it should be regarded as having lapsed.

Table 10

Nuclear installations under Agency safeguards or containing safeguarded material under agreements approved by the Board of Governorsa/

A. Research reactors and critical facilities

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

State[b]	Abbreviated name	Location	Type	Capacity MW(th)	In operation
Hungary[c]	WWR-SM	Budapest	Tank	5.00	x
	ZR-4 and ZR-6	Budapest	Critical Facility	0.00	x
	Training reactor	Budapest	Pool	0.01	x
Indonesia	PRAB (TRIGA H)	Bandung	Triga H	1.00	x
Iran[c]	TSPRR	Teheran	Pool	5.00	x
Iraq[c]	IRT-2000	Baghdad	Pool	2.00	x
Israel	IRR-1	Soreq	Pool	5.00	x
Japan	AHCF	Tokai-Mura	Critical Facility	0.00	x
	DCA	Oarai-Machi	Critical Facility	0.00	x
	FCA	Tokai-Mura	Critical Facility	0.01	x
	HTR	Kawasaki-shi	Pool	0.10	x
	JMTR	Oarai-Machi	Tank	50.00	x
	JMTR-CA	Oarai-Machi	Critical Facility	0.00	x
	JPDR	Tokai-Mura	Boiling-water	90.00	x
	JRR-2	Tokai-Mura	Tank	10.00	x
	JRR-3	Tokai-Mura	Tank	10.00	x
	JRR-4	Tokai-Mura	Pool	1.00	x
	Kinki University	Kowakai	UTR-B	0.00	x
	KUR	Kumatori-cho	Pool	5.00	x
	KUCA	Kumatori -cho	Critical Facility	0.00	x
	NSRR	Tokai-Mura	Triga (pulse)	0.3	
	Musashi College of Technology	Kawasaki-shi	Triga 11	0.10	x
	NAIG-CA	Kawasaki-shi	Critical Facility	0.00	x
	Rikkyo University	Nagasaka	Triga II	0.10	x
	SHCA	Tokai-Mura	Critical Facility	0.00	x
	TCA	Tokai-Mura	Critical Facility	0.00	x
	TODAI	Tokai-Mura	Fast Neutron Source Reactor	0.002	x
	TTR	Kawasaki -shi	Pool	0.10	x
	"Mutsu" (Nuclear Ship)	Minato-Machi Mutsu	PWR	36.00	x
	JOYO	Oarai	EBR	50.00	
Korea, Republic of[c]	KRR - TRIGA II	Seoul	Triga II	0.10	x
	KRR - TRIGA III	Seoul	Triga 111	2.00	x
Mexico[c]	Centro Nuclear de Mexico	Ocoyoacac	Triga 111	1.00	x
	Training reactor facility	Mexico City	SUR-1OO	0.00	x
Norway[c]	JEEP-II	Kjeller	Tank	2.00	x
	HBWR	Halden	HBWR	25.00	x
Pakistan	PARR	Rawalpindi	Pool	5.00	x
Philippine[c]	PRR-1	Diliman, Quezon City	Pool	1.00	x
Poland[c]	EWA	Swierk	Tank	8.00	x
	Anna and Agata	Swierk	Critical Facility	0.00	x
	Maria	Swierk	Tank	30.00	x
Portugal	RPI	Sacavem	Tank	1.00	x
Romania[c]	VVR-S	Margurele	Tank	10.00	x
South Africa	SAFARI-1	Pelindaba	Tank	20.00	x

State[b/]	Abbreviated name	Location	Type	Capacity MW(th)	In operation
Spain	JEN-1 and JEN-2	Madrid	Pool	3.00	x
	CORAL-1	Madrid	Fast Critical Facility	0.00	x
	ARBI	Bilbao	Argonaut	0.01	x
	ARGOS	Barcelona	Argonaut	0.01	x
Sweden[c/]	R2 and R2-O	Studsvik	Tank and Pool	50.00	x
	KRITZ and R-O	Studsvik	Critical Facility	0.00	x
Switzerland	Proteus	Würenlingen	Critical Facility	0.00	x
	Saphir	Würenlingen	Pool	5.00	x
	Diorit	Würenlingen	HW	30.00	x
	Crocus	Lausanne	Pool	0.00	x
	AGN201P	Geneva	Solid homogeneous	0.00	x
	AGN211P	Basel	Pool	0.00	x
Thailand[c/]	TRR-1	Bangkok	Pool	1.00	x
Turkey	TR-1	Istanbul	Pool	1.00	x
United Kingdom	Zebra	Winfrith	Critical Facility	0.00	x
Uruguay[c/]	RUDI	Montevideo	Lockheed	0.10	
Yugoslavia[c/]	Triga II	Ljubljana	Triga II	0.25	x
	RA and RB	Vinca	Heavy-water Critical Facility	6.5	x
Zaire[c/]	Triga	Kinshasa	Triga 11	1.00	x

B. Nuclear power stations

State[b]	Name of power station	Location	Type	Capacity Mw(e)	In operation
Argentina	Atucha Nuclear Power Station	Atucha	PHWR	319	x
	Cordoba Nuclear Power Station	Rio Tercero	Candu	600	
Austria[c]	Tullnerfeld	Tullnerfeld	PWR	700	-
Bulgaria[c]	Kozloduy I	Kozloduy	PWR	880	x
Canada[c]	Pickering (4 units)	Pickering, Ontario	Candu	2032	x
	NPD	Ralphton, Ontario	Candu	22	x
	Gentilly	Gentilly, Quebec	Candu	250	x
	DPGS	Kincardine, Ontario	Candu	208	x
	Bruce I	Douglas Point, Ontario	Candu	750	
China, Republic of	FNPS-1	Ching-San	BWR	636	
Czechoslovakia[c]	A1	Bohunice	HWGC	143	x
Finland[c]	Loviisa	Loviisa	PWR	880	-
German Democratic Republic[c]	Rheinsberg PWR	Rheinsberg	PWR	80	x
	Bruno Leuschner PWR	Greifswald	PWR	880	x
India	Tarapur - TAPS	Tarapur	BWR	380	x
	Rajasthan - RAPS	Rajasthan	Candu	400	x (for 200)
Japan	Tokai	Tokai-Mura	Magnox	154	x
	Tsuruga	Tsuruga	BWR	357	x
	Mihama-1	Mihama-Fukai	PWR	340	x
	Mihama-2	Mihama-Fukai	PWR	500	x
	Fukushima-1	Okuma-Fukushima	BWR	460	x
	Fukushima-2	Okuma-Fukushima	BWR	784	x
	Fukushima-3	Okuma-Fukushima	BWR	784	x
	Fukushima-5	Fukushima	BWR	784	
	Shimane	Kashima-cho	BWR	460	x
	Hamaoka 1	Hamaoka	BWR	540	x
	Takahama-1	Takahama	PWR	826	x
	Takahama-2	Takahama	PWR	826	x
	Genkai-1	Kyushu	PWR	559	x
	Mihama-3	Mihama-Fukui	PWR	826	
Korea[c]	Kori-1	Kori	PWR	564	
Mexico[c]	Laguna Verde Power Station	Laguna Verde, Vera Cruz	BWR	650	
Pakistan	KANUPP	Karachi	Candu	125	x
Spain	José Cabrera	Almonacid de Zorita	PWR	153	x
	Santa Maria de Garona	Province de Burgos	BWR	440	x
Sweden[c]	Oskarshamn I	Oskarshamn	BWR	440	x
	Oskarshamn II	Oskarshamn	BWR	580	x
	Ringhals I	Near Göteborg	BWR	760	x
	Ringhals II	Near Göteborg	PWR	830	x
	Barsebäck I	Near Malmö	BWR	580	x
Switzerland	Mühleberg	Mühleberg	BWR	306	x
	Beznau I	Beznau	PWR	350	x
	Beznau II	Beznau	PWR	350	x

C. Conversion plants, fabrication plants and chemical reprocessing plants including pilot plants

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

D. Other accountability areas covering more than one effective kilogram of nuclear material

Australia[c/]	Research Laboratory. Lucas Heights
Canada[c/]	Chalk River Nuclear Laboratories
Czechoslovakia[c/]	Research Laboratories, Rez
German Democratic Republic[c/]	Miscellaneous Locations combined in one material balance area
Hungary[c/]	Institute of Isotopes
Japan	Tokyo University (Tokai)
Poland[s/]	Institute of Nuclear Research, Swierk Miscellaneous Locations combined in one material balance area
Sweden[c/]	Central Hot Laboratory, Studsvik Laboratories and storages, Studsvik (except for KRITZ and RO) Miscellaneous Locations combined in one material balance area
Switzerland	Federal Institute of Reactor Research, Würenlingen
United Kingdom	Zebra Storage Facility, Winfrith Windscale Storage Facility, Windscale
United States of America	Argonne National Laboratory

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

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

c/ NPT Safeguards Agreement.

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

e/ Pilot plant.

ANNEX M

OUTLINE OF REGIONAL NUCLEAR FUEL CYCLE CENTER SUMMARY REPORT

RFCC STUDY PROJECT

SUMMARY REPORT

OUTLINE

VOLUME I – SUMMARY

		**Approximate number of manuscript pages
	Foreword – credits	
1.	Introduction	15 pp.
	1.1 Problems in completion of the back-end of the nuclear fuel cycle.	
	1.2 Presentation of the RFCC concept.	
	1.3 Description of the economic analytical approach-modelling, programming and characteristic data.	
	1.4 Value and limitations of characteristic data.	
	1.5 Other factors related to the RFCC concept – description of the associated studies.	
2*	Economic Studies and other Areas of Research for the RFCC (Summaries of Associated Studies)	155 pp.
	2.1 Presentation of alternative fuel cycle strategies.	
	2.2 Discussion of results.	
	2.3 Constraints and other considerations- sensitivity	
	2.4 Institutional and Legal	
	2.5 Organization and Administration.	
	2.6 Financial	
	2.7 Health, Safety and Environment	
	2.8 Materials Control	
	2.9 Public Acceptance	
3*	Conclusions and Recommendations	
Appendix		15 pp.
	Organization of the RFCC Study	
Index		
	Vol. I total :	185 pp.

**To be determined after consultation with the groups concerned.

VOLUME II BACKGROUND

4.	Introduction	20 pp.	
	4.1 Scope of the Study - methods of work		
	4.2 Brief description of contents of Volume **II**		
	4.3 Relationship to contents of **Volume I**		
5.	Analytical Methodology	45 pp.	
	5.1. Description of mathematical models and computer programme.		
	5.2 Assumptions, constraints and other factors related to the processes and operations.		
	5.3 Economic and cost evaluations - investments and schedules.		
	5.4 Correlation between mathematical models and process flow models - other testing of models.		
6.	Process Flow Models - Characteristic operation-s and Cost Data		
	6.1. Power Generation - Spent Fuel Data	30 pp.	
	6.2 Spent Fuel Storage	10 pp.	
	6.3 Fuel Reprocessing	60 pp.	
	6.4 Waste Management	60 pp.	260 pp,
	6.5 Mixed-Oxide Fuel Element Fabrication	60 pp.	
	6.6 Radioactive Material Transport	25 pp.	
	6.7 *Summary*- synthesis of back-end **of fuel cycle**	15 pp.	
7.	Associated Studies		
	7.1 **Institutional and Legal**	60 pp.	
	7.2 **Organization and Administration**	60 pp.	
	7.3 **Financial**	35 pp.	
	7.4 **Health, Safety and Environment**	45 pp.	
	7.5 **Materials Control** Process Controls	20 pp.	
	7.6 " " Safeguards	35 pp.	355 pp.
	7.7 " " Physical Security	**35 pp.**	
	7.8 **Public Acceptance**	**30** pp.	
	7.9 **Summary**	**15 pp.**	
Appendices		**20** pp.	
	Vol. II **Total :**	880 pp	
Glossary	**Vols. I and II Total:**	865 pp.	
Index			

REGIONAL NUCLEAR FUEL CYCLE CENTERS
IAEA STUDY PROJECT
SEPTEMBER 1976

The concept of regional fuel cycle centers has attracted wide interest as a possible approach towards meeting the fuel cycle requirements of many countries. Because of the many potential advantages, this concept has been endorsed by the Member States in discussions at the General Conference of the International Atomic Energy Agency and at the General Assembly of the United Nations. Accordingly, the International Atomic Energy Agency, in 1975, initiated a detailed study of the RFCC concept.

It should be emphasized that the immediate aim of the Agency's Study is to assist the Member States in evaluating the relative merits of the RFCC approach to establishing fuel cycle facilities. As there is likely to be a substantial shortage of fuel reprocessing capacity during the next ten years, it is imperative that the Member States are able to take decisions as to how long they should plan to store the spent fuel, and find answers to difficult and elusive questions as to whether they should adopt an interim thermal reactor mixed -oxide fuel strategy, and what value plutonium is likely to have for use as recycle fuel in thermal reactors or in fast breeders.

As the nuclear energy field is one in which long-range planning is vital, e. g. one needs to allow for an 8-12 years lead time for the construction and commissioning of a fuel reprocessing plant after a decision to build has been taken, the study is based on the premise that Governments would, regardless of the Agency Study, be assessing the potential of the various fuel cycle strategies in the light of their respective situations. The Study, therefore, is being pursued with a view to assisting Member States with their own evaluation and decision-making processes.

The RFCC concept is based on multinational cooperation in planning and setting up the fuel cycle facilities in a phased manner in relation to the other alternative options – (1) of each country setting up its own purely national facilities; and (2) of countries looking towards reliance on commercial services being available from existing or expanded facilities in the countries which currently have the necessary technical capability in view of their long-standing experience in all major phases of the nuclear field.

As the RFCC concept envisages multinational partnership in fuel cycle activities, it would provide a new dimension of assurance that proliferation of small fuel reprocessing plants would be avoided, and that the safeguards functions of the Agency, as also contemplated under the NPT, would be further facilitated and complemented. Co-location of the spent fuel management and plutonium recycle facilities would also have the advantage of minimizing the risks associated with the storage and shipment of plutonium as related to physical security.

The Agency Study is presently concerned mainly with what is referred to as the "back-end" of the fuel cycle because that is the portion that can be considered as problematic at present. Alternative choices need to be

examined now in regard to management of the spent fuel from the current generation of reactors. The Member States desiring to pursue a significant power programme will have to do extensive and comprehensive analysis and planning in this area so as to select the most appropriate strategy for their needs for the period 10-30 years from now. A regional multinational framework for evaluating the options and reaching conclusions on the various strategy alternatives could offer substantial advantages. The Agency study effort can provide some assistance to any group of interested Member States even as provisional results from this study become available and specific case studies could also be taken up if so desired.

As the Study has progressed, it has become apparent that the variation in the cost of transport of spent fuel. as related to varying shipment distance to the possible location of an RFCC, particularly in situations where sea transport is involved, would not be very significant in relation to the total fuel cycle cost. Hence, when considering regional groupings it is not necessary that such groupings be restricted in a narrow geographical sense, but cooperation between those potential participants who are likely to have similar plans for the development of their nuclear programmed could be envisaged.

It has also become evident that the technological and financial resources that would be required to implement the establishment of such a fuel cycle center would be such that one or more partners would have to be those who are in a position to supply the technical know -how and industrial support and are able to arrange for at least part of the financial resources required. Hence, potential participants need not think only in terms of establishing entirely new facilities as existing or planned national facilities could readily be utilized as the core for a multinational fuel cycle center.

Study Project - Programme Activities

The Study Project is divided into the following three main areas, as shown in Figure:

(1) Mathematical modelling, computer programming, and analysis of alternative strategies;

(2) Development of characteristic operations and cost data for use in the model.

(3) Preparation of associated studies to provide evaluative factors and guidance relevant to the implementation of the fuel cycle center concept. This would cover institutional and legal; organizational and administrative; financial; health, safety and environmental, materials control (including physical security and safeguards); and public acceptance aspects.

For each element of the Study it has proven helpful to have one or two lead consultants work directly with the RFCC Project staff in the preparation of working documents and related background information. This preliminary input is then reviewed and revised by a group of consultants from selected Member States, and the process is repeated if considered necessary, on a broader basis to ensure full development of the

material related to that programme element. The following table shows the number of meetings already held and planned through the end of August, together with an indication of the Member States who are assisting the Agency's study effort through their experts.

PROJECT ELEMENT	MEETINGS: Held	Planned	PARTICIPATING MEMBER STATES
Mathematical Modelling	1	2	FRG, India, Sweden, USA
Fuel Reprocessing	2	3	France, FRG, Spain, Sweden, UK, USA
Waste Management	1	2	Belgium, France, FRG, India, Japan, UK, **USA**
MOX Fuel Fabrication	1	2	**France, FRG, Italy, Japan, UK, USA**
Fuel Storage		1	**Austria, Canada, France, FRG, Japan, Sweden, UK, USA**
Fuel Transport	1	1	**Austria, France, FRG, Japan, Sweden, UK, USA**
Legal-Institutional	6	1	**Australia, Austria, Belgium, Finland, France, FRG, Japan, Korea, Pakistan, Philippines. Spain, Sweden, Switzerland, UK, USA, Yugoslavia**
Organization and Administrative			
Financial			
Health, Safety and Environment			
Safeguards			
Physical Security		1	**FRG, India, Sweden, USSR, UK, USA**
Process Control			
Public Acceptance			

Mathematical Modelling and Economic Analysis of Alternative Strategies

One of the important criteria to be used in evaluating the merits of RFCC is the overall cost of spent fuel management using integrated regional facilities as compared with costs using local (national) facilities for fuel reprocessing and refabrication, taking into account the possibility of long term storage of the spent fuel without reprocessing. The primary objective of the mathematical modelling effort is to provide a methodology for analyzing possible strategies for spent fuel management. This objective is being met by development of computer programmed which describe the material flows, facility construction criteria, and capital and operating costs for the facilities used to treat the spent fuel resulting from nuclear 'power plant operation. The computer programmed use a combination of simulation and optimization approaches to the economic analysis. Many of the fuel cycle steps, such as spent fuel discharges, storage at the reactor and transport to the RFCC, are described purely in simulation modelling; others such as inventory storage at the RFCC and construction and operation of reprocessing plants are subjected to optimization modelling to determine the relative economic tradeoff between provision for spent fuel storage and addition of reprocessing capacity.

It is intended that the developed methodology be sufficiently general, flexible and easily usable that it could be used by interested Member States to evaluate the economics of spent fuel management in their particular situation. In addition, it can be used to rapidly and easily investigate the sensitivity of RFCC economic results to variations in any of the critical input data.

Simulation Model -

This model represents an attempt to describe, or "simulate", the flows of spent fuel through the various transport, storage and reprocessing facilities, to permit calculation of costs resulting from construction and operation of those facilities. The description includes facilities for plutonium storage, conversion, and mixed-oxide fuel fabrication, and facilities for waste storage, treatment, and disposal. An important distinguishing feature of this model is that the user makes all decisions regarding spent fuel inventory storage times and reprocessing plant addition schedules. By using the programme to analyze a number of possible strategies, the planner can obtain results useful in selecting the most appropriate plan for particular conditions. The user specifies a selected plan for adding all major facilities, such as fuel reprocessing plants and mixed-oxide fuel fabrication plants. The model will then determine the storage capacity needed for spent fuel inventory in advance of reprocessing. Given the facility expansion plan, spent fuel storage plan and the cost data for all facilities, the simulation model will determine the extent to which

the facilities are utilized, and the total cost of the planned strategy, including credits for recovered uranium and plutonium.

Output from the simulation model will include the capital investment schedule for the RFCC facilities, the annual expenditures for operations, the average cost per unit of spent fuel discharged from the reactors, and the total present-worth cost of the plan. The annual revenue received by the RFCC for services provided will also be computed. In addition, the computer programme will print out a complete, detailed report on the annual quantities of materials at each stage of the spent fuel management cycle.

Use of this model is not limited to the RFCC concept; it can be used also to analyze strategies involving national facilities, in order to make cost comparisons between RFCC and national strategies. Further, the user has the option of specifying that the fuel is to be stored for several decades before reprocessing plants are introduced.

It should be apparent that, although the simulation model has no inherent optimization capability, it is very useful for making comparisons between different strategies of interest to fuel cycle planners, and for making sensitivity studies involving data uncertainties. Also, the cash flow data generated by this calculation can be used as the basis for financial analysis of fuel cycle strategies.

Optimization Model-

This model represents an attempt to determine the economic optimum schedule for reprocessing plant capacity expansion, considering spent fuel discharge rates, economies of scale of larger size reprocessing plants and the added cost of interim storage facilities needed to accumulate an operating inventory for the larger plants. The planner provides various capital and operating cost data for the several possible sizes of reprocessing plants, as well as capital and operating cost data for interim storage facilities. The optimization model then determines the lowest cost strategy, from among the many feasible strategies, for spent fuel storage and reprocessing, including the cost credits for recovered uranium and plutonium.

The optimization method employed is "backward dynamic programming' [1]. This technique has the ability to select the optimum reprocessing plant expansion schedule over the planning horizon, by examining a finite number of feasible conditions, or "states", that can possibly exist in each year of the planning horizon. A "state" of the system is characterized by a discrete reprocessing capacity and a discrete amount of spent fuel in inventory storage. The dynamic programming procedure finds the schedule of reprocessing capacity and inventory storage levels which leads to the lowest cost, when present-worth discounted over the @arming horizon.

Current Status -

Both ‘of the computer models described above have been programmed in preliminary form and are used on the Agency computer. Further work is required on the mixed oxide fuel fabrication model and the waste management model, and this will be completed in the near future.

Illustrative strategies are being analyzed with the models, for the purpose of examining the effects of different schedules for reprocessing capacity expansion and to determine the sensitivity of results to various cost uncertainties, nuclear power capacity growth rates, etc. Results from these test problems will provide guidance to select more realistic strategies for further examination.

Participation by Member States

These computer models require input data describing the nuclear power capacity projected to be installed in each country serviced by the RFCC, through the year 2000. The Member States currently provide such data on planned capacity expansions, which may extend through the mid -1980's. These data are published by the Agency in the annual bulletin "Power Reactors in Member States". It would be useful if the Member States could also periodically supply updated projections of nuclear capacity through the year 2000, supplementing the presently supplied information on planned capacity.

The Member States could assist the Agency in suggesting meaningful regional groupings and reprocessing strategies to be analyzed in detail with the computer models. Continuing participation by the Member States during this phase of the economic studies would ensure that the results obtained are for realistic conditions and that the studies are carried out in a manner useful to the Member States. At the same time, the Member States would obtain experience with the analysis techniques and computer programmed used by the Agency, thus facilitating their own use of these tools for planning purposes.

Development of Characteristic Operations and Cost Data

The Agency is making studies in six technical areas, as shown in Figure 1, to provide input data to the modelling analysis of alternative strategies. These studies cover the major activities involved in the "back-end" of the fuel cycle, namely:

1. Power plant discharges of spent fuel;
2. Spent fuel storage;
3. Spent fuel reprocessing;
4. Waste management;
5. Mixed oxide fuel fabrication;
6. Radioactive material transportation.

Each of these areas is the subject of a detailed examination by Agency staff and expert consultants. These studies will identify the important operating characteristics of facilities needed in each area, characteristics which are unique to RFCC implementation, important cost data and sensitivities to size and scale of operation, lead times for facility construction, staffing requirements, etc. At this time, costs are very uncertain in all areas of spent fuel management. Very few of these facilities have been built as individual units, and none have been built in the RFCC context. Therefore, there is little base of cost experience comparable to that for nuclear power plants or front-end fuel cycle facilities. One of the goals of the Agency studies will be to determine the probable range of costs for each of the various plants needed for spent fuel

management. These ranges can then be used in the computer codes to determine whether important economic comparisons lead to different conclusions, depending on which value of costs is used. It is expected that further cost studies may be needed in some areas, in which there is high sensitivity to cost uncertainties.

Associated Studies Relating to Regional Centers

The Agency is also preparing associated studies in six areas related to the development and implementation of the regional nuclear fuel cycle center concept, as shown in Figure 1. These studies cover some of those aspects that would have to be considered by Member States contemplating use of the RFCC approach, namely:

1. institutional and legal aspects;
2. Organization and administrative aspects;
3. Financial considerations;
4. Health, safety and environmental aspects;
5. Materials control considerations;
6. Public acceptance considerations.

Each of these areas is being examined by Agency staff and expert consultants to identify the important factors, understandings and approaches needed by potential participants in implementing regional centers, as well as the constraints that would apply in the analysis of alternative fuel cycle strategies. More specifically, these studies have the following scope and objectives:

Institutional and Legal Study -

To present possible institutional arrangements and legal considerations essential to the successful implementation and operation of regional centers, taking into account past industrial experience and arrangements for other multinational ventures. A preliminary report entitled "Institutional-Legal Framework Aspects", RFCC/2, has been issued;
Organization and Administrative Study.

To develop those factors and requirements essential to the everyday operation of regional centers, especially considerations of staffing, training of technical and supervisory personnel, provisions for technical support, industrial backup, etc;

Financial Study -

To examine pertinent methodologies for financial analysis and accounting considerations, and to explore possible approaches to joint financing of multinational activities;

Health, Safety and Environment Study -

To develop considerations and requirements in those areas pertinent to the RFCC approach, especially with regard to safety standards, siting criteria, radioactive waste and effluent control, and other related health and safety matters;

Materials Control Study -

To present those aspects related to the control of nuclear materials in three areas, i. e. safeguards, physical security and process ***controls.*** The safeguards and physical security portions of the Study cover the specific advantages and other attributes that would accrue due to co-location of the spent fuel management and plutonium storage and recycle facilities operated on a multinational partnership basis. The process controls portion of the Study deals more specifically with those considerations relating to nuclear material flows including reprocessing campaigns, losses of product, accountability and inventory, product swap, etc. , that would be of interest to the participants;

Public Acceptance Study -

To examine those aspects of multinational operation of regional fuel cycle centers related to public acceptance of the RFCC approach, especially in the areas of siting, radioactive effluent control and radio-active waste management.

Preparation of Summary Report

Work on the various programme elements of the Study has proceeded at a somewhat non-uniform pace depending on the availability of experts and technical and economic data. However, it is expected that with continuing assistance from, and interest of, the Member States, it will be possible to meet the original objective of preparing a summary report on the RFCC concept, together with illustrative analyses of alternative fuel cycle strategies in time for presentation at the Conference on Nuclear Power and its Fuel Cycle to be held in Salzburg in May 1977.

ANNEX *O*

TREATY OF ROME, CHAPTER VII, ARTICLES 77-85

(b) by a person or undertaking and an international organisation or a national of a third State, where the material is processed, converted or shaped outside the Community and then returned to the original person or undertaking; or

(c) by a person or undertaking and an international organisation or a national of a third State, where the material is processed, converted or shaped inside the Community and is then returned either to the original organisation or national or to any other consignee likewise *outside the* Community designated by such organisation or national.

The persons and undertakings concerned shall, however, notify the Agency of the existence of such commitments and, as soon as the contracts are signed, of the quantities of material involved in the movements. The Commission may prevent the commitments referred to in subparagraph (b) from being undertaken if it considers that the conversion or shaping cannot be carried out efficiently and safely and without the loss of material to the detriment of the Community.

The materials to which such commitments relate shall be subject in the territories of the Member States to the safeguards laid down in Chapter Vii. The provisions of Chapter VIII shall not, however, be applicable to special fissile materials covered by the commitments rcferred to in subparagraph (c).

Article 76

On the initiative of a Member State or of the Commission, and particularly if unforeseen circumstances create a situation of general shortage, the Council may, acting unanimously on a proposal from the Commission and after consulting the Assembly, amend the

provisions of this Chapter. The Commission shall inquire into any request made by a Member State.

Seven years after the entry into force of this Treaty, the Council may confirm these provisions in their entirety. Failing confirmation, new provisions relating to the subject matter of this Chapter shall be adopted in accordance with the procedure laid down in the preceding paragraph.

CHAPTER VII

SAFEGUARDS

Article 77

In accordance with the provisions of this Chapter, the Commission shall satisfy itself that, in the territories of Member States,

(a) ores, source materials and special fissile materials are not diverted from their intended uses as declared by the users;

(b) the provisions relating to supply and any particular safeguarding obligations assumed by the Community under an agreement concluded with a third State or an international organisation are complied with.

Article 78

Anyone setting up or operating an installation for the production, separation or other use of source materials or special fissile materials or for the processing of irradiated nuclear fuels shall

declare to the Commission the basic technical characteristics of the installations, to the extent that knowledge of these characteristics is necessary for the attainment of the objectives set out in Article 77.

The Commission must approve the techniques to be used for the chemical processing of irradiated materials, to the extent necessary to attain the objectives set out in Article 77.

Article 79

The Commission shall require that operating records be kept and produced in order to permit accounting for ores, source materials and special fissile materials used or produced. The samc requirement shall apply in the case of the transport of source materials and special fissile materials.

Those subject to such requirements shall notify the authorities of the Member State concerned of any communications they make to the Commission pursuant to Article 78 **and to the first paragraph of this Article.**

The nature and the extent of the requirements referred to in the first paragraph of this Article shall be defined in a regulation made by the Commission **and approved by the** Council.

Article 80

The Commission may require that any excess special fissile materials recovered or obtained as by-products and not actually being used or ready for use shall be deposited with the Agency or in other stores which are or can be supervised by the Commission.

Special fissile materials deposited in this way must be returned forthwith to those concerned at their request.

Article 81

The Commission may send inspectors into the territories of Member States. Before sending an inspector on **his first assignment in the territory of a Member State, the Commission shall consult the State concerned;** such consultation shall suffice to cover all future assignments of this inspector.

On presentation of a document establishing their authority, inspectors shall at all times have access to all places and data and to all persons who, by reason of their occupation, deal with materials, equipment or installations subject to the safeguards provided for in this Chapter, to the extent necessary in order to apply such safeguards to ores, source materials and special fissile materials and to ensure compliance with the provisions of Article 77. Should the State concerned so request, inspectors appointed by the Commission shall be accompanied by representatives of the authorities of that State; however, the inspectors shall not thereby be delayed or otherwise impeded in the performance of their duties.

If the carrying out of an inspection is opposed, the Commission shall apply to the President of the Court of Justice for an order to ensure that the inspection be carried out compulsorily. The President of the Court of Justice shall give a decision within three days.

If there is danger in delay, the Commission may itself issue a written order, in the form of a decision, to proceed with the inspection This order shall be submitted without delay to the President of the Court of Justice for subsequent approval.

After the order or decision has been issued, the authorities of the State concerned shall ensure that the inspectors have access to the places specified in the order or decision.

Article 82

Inspectors shall be recruited by the Commission.

They shall be responsible for obtaining and verifying the records referred to in Article 79. They shall report any infringement to the Commission.

The Commission may **issue** a directive calling upon the Member State concerned to take, **by a** time limit set by the Commission, all 'measures necessary to bring such infringement to an end; it shall inform the Council thereof.

If the Member State does not comply with the Commission directive by the time limit set, the Commission or any Member State concerned may, in derogation from Articles 141 and 142, refer the matter to the **Court of Justice** direct.

Article 83

f. In the event of an infringement on **the part** of persons or undertakings of the obligations imposed on them by this Chapter, the Commission may impose sanctions on such persons or undertakings.

These sanctions shall be, in order of severity:

(a) a warning;

(b) the withdrawal of special benefits such ***as*** financial or technical assistance;

(c) the placing of the undertaking for a period not exceeding four months under the administration of a person or board appointed by common accord **of the** Commission and the State having jurisdiction over the undertaking;

(d) total or partial withdrawal of source materials or special fissile materials.

2.Decisions taken by the Commission in implementation of paragraph 1 and requiring the surrender of materials shall be enforce-

able. They may be enforced in the territories of Member States in accordance with Article 164.

By way of derogation from Article 157, appeals brought before the Court of **Justice against** decisions **of** the Commission which impose any of the sanctions provided for in paragraph 1 shall have suspensory effect. The Court of Justice may, however, on application by the Commission or by any Member State concerned. order that the decision be enforced forthwith.

There shall be an appropriate legal procedure to ensure the protection of interests that have been prejudiced.

3. **The Commission may make any recommendations to Member States concerning laws or regulations which are designed to ensure compliance in their territories with the obligations arising under this Chapter.**

4. Member States shall ensure that sanctions are enforced and, where necessary, that the infringements arc remedied by those committing them.

Article Article 84

In the application of the safeguards, no discrimination shall be made on grounds of the use for which ores, **source materials and special fissile materials arc intended.**

The scope of and procedure for the safeguards and the powers of the bodies responsible for their application shall be confined to the attainment of the objectives set out in this chapter.

The Safeguards may not extend to materials intended to meet defence requirements which are in the course of being specially

processed for this purpose or which, after being so processed, are, in accordance with an operational plan, placed or stored in a military establishment.

Article 85

Where new circumstances so require, the procedures for applying the safeguards laid down in this Chapter may, at the request of a Member State or of the commission, be adapted by the Council, acting unanimously on a proposal from the Commission and after consulting the Assembly. The Commission shall examine any such request made by a Member State.

CHAPTER VIII

PROPERTY OWNERSHIP

Article 86

Special fissile materials shall be the property of the Community.

The Community's right of ownership shall extend to all special fissile materials which are produced or imported by a Member State, a person or an undertaking and are subject to the safeguards provided for in Chapter VII.

Article 87

Member States, persons or undertakings shall have the unlimited right of use and consumption of special fissile materials which have properly come into their possession, subject to the obligations imposed on them by this Treaty, in particular those relating to safeguards, the right of option conferred on the Agency and health and safety.

Article 88

The Agency shall keep a special account in the name of the Community, called "Special Fissile Materials Financial Account".

Article 89

f. In the Special Fissile Materials Financial Account:

(a) the value of special fissile materials left in the possession of or put at the disposal of a Member State, person or undertaking shall be credited to the Community and debited to that Member State, person or undertaking;

(b) the value of special fissile materials which are produced or imported by a Member State, person or undertaking and become the property of the Community shall be debited to the Community and credited to that Member State, person or undertaking. A similar entry shall be made when a Member State, person or undertaking restores to the Community special fissile materials previously left in the possession of or put at the disposal of that State, person or undertaking.

2. Variations in value affecting the quantities of special fissile material shall be expressed for accounting purposes in such a way as not to give rise to any loss or gain to the Community. Any loss or gain shall be borne by or accrue to the holder.

ANNEX P

EURATOM, GENERAL BUDGET FOR EXPENDITURES RELATED TO SAFEGUARDS (1977)

COMMISSION OF THE EUROPEAN COMMUNITIES

PRELIMINARY DRAFT

General budget of the European Communities for the financial year 1977

VOLUME 7

SECTION III • COMMISSION

General Introduction

CHAPTER 34 EXPENDITURE RELATING TO SAFEGUARDS

Σ = 732,000 ua + JRC research @ 1.6 mua for period '77-'80 (1.7 in '80)

ARTICLE 340 ON-THE-SPOT INSPECTIONS AND OTHER MISSIONS

1. Legal basis and description of the operation

(a) Legal basis

Chapter VII of the EAEC Treaty; Commission Regulations No 7 and 8 on *safeguards;* external **obligations which the Commission has assumed in respect of non-member countries and international organizations, especially the Verification " Agreement concluded with the IAEA in Vienna.**

(b) Description of the operation

(a) **In** accordance with Article **77 of the *EAEC* Treaty, the Commission shall satisfy itself that, in the territories of the Member States:**

- **proper use is being made of nuclear materials,**
- **that the obligations assumed by the Commission in respect of non-member** countries (e.g., cooperation agreement with the United States) and international organizations (e.g., Verification ***Agreement*** **with the Agency in Vienna) are complied with,**

(b) In accordance with Article 81 of the EAEC Treaty, the Commission shall inspect all nuclear installations on Community territory which form part of the fuel cycle from the mining stage through to the reprocessing and enrichment stage. This is an on-going operation.

2. Type of expenditure

Operating costs.

3. Method of calculation and explanation of changes

(a) Method of calculation

Anticipated number of days for mission x daily allowances x average travelling expenses x additional expenses (e.g., hire of offices on the spot plus sundry expenses and if necessary the hire of cars) = overall cost = appropriation requested.

(b) Explanation of changes.

1975 Commitments	220.827 u.a.
1976 Appropriations	270.000 u.a.
1977 Request	302.000 u.a.

The increase of some 12% over the 1976 appropriation reflects the additional expenditure arising from the implementation of the Verification Agreement concluded with the IAEA in Vienna.

ARTICLE 341 COST OF TRAINING PERIODS

1. Legal basis and description of the operation

(a) Legal basis

As for Article 340,

(b) Description of the operation

Information and general and specialized vocational training:

- Courses and periods of training for Commission inspectors (at the seat in Luxembourg and at the JRC, in particular Ispra),
- Information and training periods with State and intentional organizations and institutions both within and outside the Community (e.g., USA and IAEA) which are competent in the matter of safeguards in order that inspectors can keep permanently abreast of the latest methods in this field.
- In accordance with basic Euratom standards - issued on 12 February 1959, 5 March 1962 and 17 October 1967 by the Council as Directives - the inspectors must have sufficient knowledge to be able to discern and pinpoint hazards and keep abreast of scientific progress in the field of health protection. It is therefore important that newly-recruited inspectors in particular should take part in specialized courses either at the JRC or at the national centres in the Member States.

2. Type of expenditure

Operating costs.

3* Method of calculation and explanation of changes

(a) Method of calculation

Number of participants involved in the training period and on the courses x (daily allowance x number of days' training + average traveling expenses + enrollment. expenses) = total cost = appropriation requested.

(b) Explanation

1975 Commitments	:	11.659 u.a.
1976 Appropriations	:	15.000 u.a.
1977 Request	:	22.000 u.a.

The increase in appropriations over 1976 is due to the high level of staff participation, especially of newly-recruited inspectors, in training schemes devoted to the use of new methods for inspecting nuclear installations. It is also to allow training periods to be organized for 15 inspectors on the subject of health protection.

ARTICLE 342 SAMPLING AND ANALYSIS

1. Legal basis and description of the operation

(a) Legal basis

As for Article 340.

(b) Description of the operation

Sampling and analysis in the Community's nuclear installations. The need for this arises from the application of safeguards on a physical and chemical basis, especially destructive methods. The analysis work itself is generally carried out at specialized installations such as the JRC (e.g., CBNM) or national research centres which have to be paid for such work.

2, Type of expenditure

Technical operating costs.

3. Method of calculation and explanation of changes

(a) Method of calculation

Cost of the material + cost of sampling + packaging cost + transport cost + insurance cost + cost of analysis x number of samples = total cost = appropriation requested.

(b) Explanation of changes

1975 Commitments	77.334 u.a.
1976 Appropriations	150.000 u.a.
1977 Request	174.000 u.a.

Since the Commission is bound by the Treaty to inspect the nuclear installations of the Community by carrying out sampling operations the amount requested reflects the increased obligations arising from the entry into force of the Verification Agreement and the inspections which have to be carried out on the territory of the new Member States. These new inspections have led to an increase in the work-load of about 16% over the 1976 financial year.

ARTICLE 343: SCIENTIFIC AND TECHNICAL WORK AND EQUIPMENT

1. Legal basis and description of the operation

(a) Legal basis

Same as for Article 340.

(b) Description of the operation

- Acquisition, maintenance and replacement of technical equipment (including spare parts and accessories) which are indispensable to compliance with the obligations laid down in Chapter VII of the Euratom Treaty and of the Commission's "external commitments" towards non-member countries and international organizations are to be safeguarded in accordance with the provisions laid down in Articles 77 and 81 of the Euratom Treaty.

- Scientific and technical work involved in the design, research, development and application of a large number of techniques for the measurement and supervision of fissile materials in accordance with the provisions laid down in Article 77 of the Euratom Treaty.

2. Type of expenditure

Technical operating costs.

3. Method of calculation and explanation of changes

(a) Method of calculation

- Purchase price of new material (equipment, instruments, apparatus) + maintenance and repair of existing material = total cost = appropriation requested.

- The benefits are calculated according to the nature of each application; prices always vary for reasons such as:

  - market sensitivity to price fluctuations,

  - very complex and therefore costly projects.

(b) Explanation of changes

1975 Commitments	138.317 u.a.
1976 Appropriations	150.000 u.a.
1977 Request	**186.000 u.a.**

Following the entry into force of the Verification Agreement and in anticipation of the provisions of the new Regulation concerning new methods of inspection, inspectors must be provided with the most up-to-date and efficient equipment possible. This leads to an increase in the volume of scientific equipment purchased and means that the equipment must be continually adapted to suit technical requirements.

Consequently, the percentage increase in 1977 will be 24% over the appropriations for the preceding budget year.

ARTICLE 344: EXPENDITURE ON FORMAL AND INFORMAL MEETINGS

1. Legal basis and description of the operation

(a) **Legal basis**

As for Article 340.

(b) Description of the operation

In accordance with the provisions of Article 77 of the Euratom Treaty, the Commission must satisfy itself that, in the territories of Member States:

- proper use is being made of nuclear materials,
- **that the obligations assumed by the Commission towards** non-member countries and international organizations are complied with.

Accordingly, the Commission must either take part in or *organize* the following meetings:

- meetings relating to the implementation of the Verification Agreement concluded with the IAEA: 20 meetings planned,
- meetings *on* the procedures for drawing up physical inventories and for the use of equipment, seals, etc: 5 meetings planned,
- meetings of the Advisory Committee on **Safeguards: 2 meetings planned.**

2. Type of expenditure

Technical operating costs.

3. Method of calculation and explanation of changes

(a) Method of calculation

Number of experts x (daily allowances x number of days present + average traveling expenses) = total cost = appropriation requested.

(b) Explanation of changes,

- Commitments	1975	**5.695 u.a.**
- Appropriations	1976	25.000 u.a.
- Request	1977	26.000 u.a.

The appropriation requested for 1977 remains entirely within the normal limits of price increases.

ARTICLE 345 - EXPENDITURE ON HEALTH CHECKS AS PART OF THE MEASURES FOR PROTECTING THE HEALTH OF STAFF EXPOSED TO RADIATION

1. Legal basis and description of the operation

(a) Legal basis

EAEC Treaty (Chapter III - Articles 31 and 33)
National laws on "basic standards".

(b) Ascription of the operation

Any person exposed in the course of his work to radiation must be protected against the attendant dangers. This applies in general especially to persons who work in nuclear installations and to the Commission inspectors who carry out the safeguard checks in accordance with the provisions of Article 77 of the Euratom Treaty.

2. Type of expenditure

JRC scientific activities.

3. Method of calculation and explanation of changes

(a) Method of calculation

(Number of inspectors x cost of the various activities assigned to each inspector) + cost of the exceptional allowances in case of irradiation + requisite equipment for this operation + any administrative costs (for example; administration) = total cost.

(b) Explanation of changes

- Commitments	1975	20.000 u.a. (transfer)
- Appropriations	1976	20.000 u.a.
- Request	1977	22.000 u.a.

This income takes account of the normal trend *in the costs* **for** these operations.

PROTOCOL

Article 1

This Protocol amplifies certain provisions of the Agreement and, in particular, specifics the conditions and means according to which co-operation in the application of the safeguards provided for Under the Agreement shall be implemented in such a way as to avoid unnecessary duplication of the Community's safeguards activities.

Article 2

The Community shall collect the information on facilities and on nuclear material outside facilities to be provided to the Agency under the Agreement on the basis of the agreed indicative questionnaire annexed to the Subsidiary Arrangements.

Article 3

The Agency and the Community shall carry out jointly the examination of design information provided for in Article 46(a) to (f) of the Agreement and shall include the agreed results thereof in the Subsidiary Arrangements. The verification of design information provided for in Article 48 of the Agreement shall be carried out by the Agency in co-operation with the Community.

Article 4

When providing the Agency with the information referred to in Article 2 of this Protocol, the Community shall also transmit information on the inspection methods which it proposes to use and the complete proposals, including estimates of inspection efforts for the routine inspection activities, for Attachments to the Subsidiary Arrangements for facilities and material balance areas outside facilities.

Article 5

The preparation of the Attachments to the Subsidiary Arrangements shall be performed together by the Community and the Agency.

Article 6

The Community shall collect the reports from the operators, keep centralised accounts on the basis of these reports and proceed with the technical and accounting control and analysis of the information received.

Article 7

Upon completion of the tasks referred to in Article 6 of this Protocol the Community shall, on a monthly basis, produce and provide the Agency with the inventory change reports within the time limits specified in the Subsidiary Arrangements.

Article 8

Further, the Community shall transmit to the Agency the material balance reports and physical inventory listings with frequency depending 011 the frequency of physical inventory taking as specified in the Subsidiary Arrangements.

Article 9

The form and format of reports referred to in Articles 7 and 8 of this Protocol, as agreed between the Agency and the Community, shall be specified in the Subsidiary Arrangcmcnts.

Article 10

The routine inspection activities of the Community and of the Agency, including the inspections referred to in Article 84 of the Agreement, for the purposes of the Agreement, shall be coordinated pursuant to the provisions of Articles 11 to 23 of this Protocol.

Article 11

Subject to Articles 79 and 80 of the Agreement, in determining the actual number, intensity, duration, timing and mode of the Agency inspections in respect of each facility, account shall be taken of the inspection effort carried out by the Community in the framework of its multinational system of safeguards pursuant to the provisions of this Protocol.

Article 12

Inspection efforts under the Agreement for each facility shall be determined by the use of the criteria of Article 81 of the Agreement. Such criteria shall be implemented by using the rules and methods set forth in the Subsidiary Arrangements which have been used for the calculation of the inspection efforts in respect of specific examples attached to the Subsidiary Arrangements. These rules and methods shall be reviewed from time to time, pursuant to Article 7 of the Agreement, to take into account new technological developments in the field of safeguards and experience gained.

Article 13

Such inspection efforts, expressed as agreed estimates of the actual inspection efforts to be applied, shall be set out in the Subsidiary Arrangements together with relevant descriptions of verification approaches and scopes of inspections to be carried out by the Community and by the Agency. These inspection efforts shall constitute, under normal operating conditions and under the conditions set out below, the actual maximum inspection efforts at the facility under the Agreement;

(a) The continued validity of the information on Community safeguards provided for in Article 32 of the Agreement, as specified in the Subsidiary Arrangements;

(b) The continued validity of the information provided to the Agency in accordance with Article 2 of this Protocol;

(c) The continued provision by the-Community of the reports pursuant to Articles GO and 61, 63 to 65 and 67 to 69 of the Agreement, as specified in the Subsidiary Arrangements;

(d) The continued application of the co-ordination arrangements for inspections pursuant to Articles 10 to 23 of this Protocol, as specified in the Subsidiary Arrangements; and

(e) The application by the Community of its inspection effort with respect to the facility, as specified in the Subsidiary Arrangements, pursuant to this Article.

Article 14

(a) Subject to the conditions of Article 13 of this Protocol, the Agency inspections shall be carried out simultaneously with the inspection activities of the Community. Agency inspectors shall be present during the performance of certain of the Community inspections,

(b) " Subject to the provisions of paragraph (a), whenever the Agency can achieve the purposes of its routine inspections set out in the Agreement, the Agency inspectors shall implement the provision of Articles 74 and 75 of the Agreement through the observation of the inspection activities of the Community inspector. provided, however, that:

than through the observation of the inspection activities of the Community inspectors, which can be foreseen, these shall be specified in the Subsidiary Arrangements; and

(ii) in the course of an inspection, Agency inspectors may carry out inspection activities other than through the observation of the inspection activities of the Community inspectors where they find this to be essential and urgent, if the Agency could not otherwise achieve the purposes of its routine inspections and this was unforeseeable.

Article 15

The general scheduling and planning of the Community inspections under the Agreement shall be established by the Community in co-operation with the Agency.

Article 16

Arrangements for the presence of Agency inspectors during the performance of certain of the Community inspections shall be agreed in advance by the Agency and the Community for each type of facility, and to the extent necessary, for individual facilities.

Article 17

In order to enable the Agency to decide, based on requirements for statistical sampling, as to its presence at a particular Community inspection, the Community shall provide the Agency with an advance statement of the numbers, types and contents of items to be inspected according to the information available to the Community from the operator of the facility.

Article 18

Technical procedures in general for each type of facility and, to the extent necessary, for individual facilities, shall be agreed in advance by the Agency and the Community, in particular with respect to:

(a) The determination of techniques for random selection of statistical samples; and

(b) The checking and identification of standards.

Article 19

The co-ordination arrangements for each type of facility set out in the Subsidiary Arrangements shall serve as a basis for the co-ordination arrangements to be specified in each Facility Attachment.

Article 20

The specific co-ordination actions on matters specified in the Facility Attachments pursuant to Article 19 of this Protocol shall be taken between Community and Agency officials designated for that purpose.

Article 21

The Community shall transmit to the Agency its working papers for those inspections at which Agency inspectors were present and inspection reports for all other Community inspections performed under the Agreement.

Article 22

The samples of nuclear material for tile Agency shall be drawn from the same randomly selected batches of items as for the Community and shall be taken together with Community samples, except when the maintenance of or reduction to the lowest practical level of the Agency inspection effort requires independent sampling by the Agency, as agreed in advance and specified in the Subsidiary Arrangements.

Article 23

The frequencies of physical inventories to be taken by facility operators and to be verified for safeguards purposes will be in accordance with those laid down as guidelines in the Subsidiary Arrangements. If additional activities under the Agreement in relation to physical inventories are considered to be essential, they will be discussed in the Liaison Committee provided for in Article 25 of this Protocol and agreed before implementation.

Article 24

Whenever the Agency can achieve the purposes of its ad hoc inspections set out in the Agreement through observation of the inspection activities of Community inspectors, it shall do so.

Article 25

(a) With a view to facilitating the application of the Agreement and of this Protocol, a Liaison Committee shall be established, composed of representatives of the Community and of the Agency.

(b) The Committee shall meet at least once a year:

(i) To review, in particular, the performance of the co-ordination arrangements provided for in this Protocol, including agreed estimates of inspection efforts;

(ii) To examine the development of safeguards methods and techniques; and

(iii) To consider any questions which have been referred to it by the periodic meetings referred to in paragraph (c).

(c) The Committee shall meet periodically at a lower' level to discuss, in particular and to the extent necessary, for individual facilities, the operation of the co-ordination arrangements provided for in this Protocol, including, in the light of technical and operational developments, up-dating of agreed estimates of inspection efforts with respect to changes in throughput, inventory and facility operational programmed, and the application of inspection procedures in different types of routine inspection activities and, in general terms, statistical sampling requirements. Any questions which could not be settled would be referred to the meetings mentioned in paragraph (b).

(d) Without prejudice to urgent actions which might be required under the Agreement, should problems arise in the application of Article 13 of this Protocol, in particular when the Agency considered that the conditions specified therein had not been met, the Committee would meet as soon as possible at the suitable level in order to assess the situation and to discuss the' measures to be taken. If a problem could not be settled, the Committee may make appropriate proposals to the Parties, in particular with the view to modifying the estimates of inspection efforts for routine inspection activities.

(e) The Committee shall elaborate proposals, as necessary, with respect to questions which require the agreement of the Parties.

ANNEX R

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LIST OF REFERENCES

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