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RECIPROCAL INSPECTIONS ON A BILATERAL BASIS AND MULTILATERAL INSPECTIONS BY AN INTERNATIONAL AGENCY, OF NUCLEAR ESTABLISHMENTS FOR PEACEFUL PURPOSES, IN THE TERRITORY OF NON-NUCLEAR-WEAPON STATES AND SAFEGUARDS AGAINST INDUSTRIAL ESPIONAGE THROUGH SUCH INSPECTIONS

by

I.H. Usmani *

* This paper by Dr. I.H. Usmani, Chairman, Pakistan Atomic Energy Commission, has been prepared at the request of the Secretary-General. The views and opinions expressed therein are those of the author and do not imply the expression of any opinion on the part of the Secretary-General.

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CONTENTS

I. BASIC FACTS

1. To appreciate the complex issues involved in safeguarding nuclear materials and facilities against diversion and uses for military purposes, some background information relating to the structure of the atom, the mechanism oftransmutation of elements, and the fission and fusion processes etc., is essential. This is given in Appendix I. Briefly speaking there are three basic facts which are important and significant:-

Singularity of Uranium:

(i) Of all the 92 elements which exist in nature there is only one element, namely, uranium which is the last (92nd) in the periodic table and the heaviest, 0.7% of which in the form of isotope U-235 is fissionable. The rest, namely 99.3% is accounted for by the non-fissionable isotope U-238. Another very important feature of the phenomenon of fission of U-235 is that the fission of one atom of U-235 leads to the fission of another, thus setting up a chain reaction which under certain conditions, can be sustained so that the energy released from the fission of the atoms of U-235 can be harnessed.

There is one more element that occurs in nature, namely, thorium (Th-232) which if exposed to neutrons is transmuted or converted into the isotope U-233 which is fissionable and behaves like U-235, but the technology of conversion and separation has not yet been fully developed for large scale production.

Scale of liberation of energy:

(ii) When one pound of coal is burnt about 3.5 units (Kwh) of energy in the form of heat are liberated. Similarly, when one pound of oil burns, about 5.5 units (Kwh) of energy are released. But when one pound of uranium-235 is fissioned, the energy liberated is of the order of 10.5 million units (Kwh)! It is this vast difference in the scale of energy produced which has led to the development of nuclear bombs on the military side and the generation of electricity from nuclear power reactors on the peaceful civilian side. The only difference between these two applications of atomic energy is that in the case of a bomb, the liberation of the fission energy is uncontrolled while in the case of a reactor it can be controlled at any desired level.

Production of Plutonium:

(iii) While the isotope U-235 fissions or "burns" as fuel in a reactor, the isotope U-238 gets converted or transmuted into a new element called plutonium whose isotopes Pu-239 and Pu-241 are fissionable but the istope Pu-240, and Pu-242 are not. Thus, the "burn-up" of uranium "fuel" in a reactor leads to the simultaneous generation of a new fuel having the same properties of fissioning as the original uranium fuel had. It is as if coal after burning, were to leave behind ash which could be reburnt as coal. In other words, a country having a nuclear reactor as a part of its peaceful nuclear programme automatically acquires the capability of producing fissionable material in the form of plutonium as a by-product on its own territory which after chemical reprocessing could be recovered and either used as fuel for generation of energy for peaceful purposes or diverted for use as charge for nuclear explosives and bombs. In fact, the emergence of five nuclear-weapon powers in less than 20 years after the detonation of the first two bombs during the last war, is largely due to this unique phenomenon of breeding of plutonium in a reactor using uranium as fuel. Appendix II contains graphs showing the build up of plutonium with its isotopic composition in different types of reactors against burn-up of uranium fuel. As time goes on, and as technology develops, more and more countries will take to generation of cheap and abundant electricity from nuclear power reactors, particularly those which have a high-cost fuel economy, so that all such countries could have large inventories of fissionable plutonium which if not safeguarded could be diverted for military purposes. How serious the problem of multiplication of nuclear-weapon states could become, can be seen from Appendix III which contains a statement showing the projection of nuclear power generation up to 1985 in the nuclear-weapon states and the non-nuclear-weapon states in different regions of the world. The total production of plutonium by 1970 will be of the order of 6500 kgms/year of which 1500 kgms/year will be breeding in the reactors of non-nuclear-weapon states. These figures are likely to jump by a factor of ten by 1980.

2. From the basic facts stated above, it is clear that no country can acquire a nuclear weapon capability unless it can produce special fissionable materials either in the form of the isotopes of uranium, U-233 and U-235 or the isotope of plutonium-239 (Pu-239) in sufficient quantities. Thus, in order to prevent the diversion of these materials to military purposes there has to be some system of safeguards on a bilateral, regional or international basis, which should be applied effectively at selected stages and points along the two routes, namely, the uranium route and the plutonium route. The chances of industrial espionage during the application of safeguards along these routes and the remedial measures have been fully discussed in the paragraphs 17-22. It is, however, necessary to understand the implications in the processes and plants that have to be established along these routes to obtain the special fissionable materials.

II. THE URANIUM AND PLUTONIUM ROUTES:

The Uranium Route:

3. The uranium route requires either the irradiation of thorium in a reactor where the isotope thorium-232 (Th-232) is transmuted into the isotope U-233 or the establishment of an isotope separation plant, which can separate, from a given quantity of natural uranium, the fissionable isotope U-235 (0.7%) from the heavy istope U-238 (99.3%). The technology of thorium fuelled reactors has not yet been satisfactorily developed but it may be perfected during the life-time of NPT so that the thorium fuel cycle may have to be safeguarded in a manner similar to the uranium fuel cycle discussed later in this paper.

4. Reverting to the separation of U-235 from U-238, it may be pointed out that no chemical process can be used for separation because U-235 and U-238, being isotopes of the same element, are chemically indistinguishable from one another. The separation of U-235 is, therefore, achieved through physical methods or processes which exploit the small difference in their atomic weights. The three most well-known processes are:-

(a) The gaseous diffusion process

(b) The ultra centrifuge process

and (c) The electromagnetic process.

5. The Diffusion Process: Of these the gaseous diffusion process has been found to be most economical, having a good input-output ratio. In a diffusion plant, natural uranium containing a mixture of U-238 (99.3%) and U-235 (0.7%), is first treated with hydrofluoric acid and converted into uranium hexafluoride (UF_6) gas which is pumped through a series of very fine membranes arranged in a row that allow the lighter atoms of U-235 to diffuse through more easily than those of U-238. The gas is pumped and repumped till at the end of the row of membranes, the hexafluoride comes out enriched in U-235 at the desired level. For weapons the enrichment in U-235 is supposed to be of the order of 90-95%. From the gaseous hexafluoride the reduction to uranium oxide or metal can be done by ordinary chemical means. For most of the power reactors the enrichment of fuel is in the range of 3-5% in the form of uranium oxide (UO_2) for water moderated reactors and in the form of uranium metal in the case of graphite moderated reactors. It may be pointed out that so far only the five nuclear-weapon states possess diffusion plants and it is very unlikely that any other country can establish it unless that country is highly industrialised and resourceful. This can be judged from the fact that the cost of a diffusion plant of economic size is estimated to be of the order of

$ 700-1000* million and it requires as much as 800,000 kilowatts of electric power to operate and maintain it. Although the principles of its working are known, the technology of a diffusion plant is largely classified. It is, however, known that the cost of U-235 recovered from the diffusion plants in the United States is of the order of $ 11000-12000 per kg. if the cost of natural uranium feed is taken to be $ 20 per kg.**

6. The Ultra Centrifuge Process: Another physical process which has been successfully developed recently, employs the ordinary principle of the centrifugal force according to which, if a mixture in the form of a fluid is churned with sufficiently high speed the lighter portion remains at the centre while the heavier portion goes to the periphery. The most familiar example of this principle in every day life, is the separation of cream from milk by churning. The modern centrifuges can operate at ultra high speeds because new materials and alloys have been developed which can stand the high temperatures generated by such speeds. The gas centrifuges developed to separate U-235 from U-238 are simpler to manufacture and operate than the diffusion plants but their technology has also been classified. From what is known, however, it appears that the centrifugal process can produce low-enrichments required for reactor fuel quite economically but the recovery of U-235, enriched up to 90-95%, required for weapons, would be very costly. Nonetheless the point is that a non-nuclear-weapon state unmindful of the cost can use this method to recover sufficient quantities of U-235, for making nuclear weapons. There is every indication that the technology of the ultracentrifuges would develop very fast and they would become good sources of production of low enriched uranium fuel for power reactors thereby reducing the dependence on supplies of such fuel from the nuclear-weapon states only. In other words, their establishment is likely to become a feature of the peaceful programme of any country trying to become independent in the matter of enriched fuel supplies. The need to safeguard such plants is, therefore, too obvious to emphasize.

7. The Electromagnetic Process: In this process the uranium hexafluoride gas is first passed through an electric field so that the uranium atoms acquire an electric charge and the gas is "ionized." The "ions" or the electrically charged

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* Nucleonics, February, 1967, pp.55-56.

** Report of the Study Committee on Toll Enrichment. Atomic Industrial Forum, New York, October, 1965.

atoms are then subjected to a very strong magnetic field which deflects them into well defined "arcs" or bends. As the lighter atoms of U-235 are deflected farther than those of U-238, the gas containing U-235 atoms can be collected at the pre-calculated angle and thereafter reduced into uranium oxide or uranium metal required for fuelling a reactor. The electromagnetic separation process was first used by the United States for its early weapons programme but was later abandoned in favour of the diffusion method because of the low output and high cost of enriched uranium. This is not to say that such a plant cannot be established by a non-nuclear weapon state to produce U-235 under the garb of a peaceful programme and as such activities towards that end have to be closely safeguarded to prevent diversion of the end product to weapons production.

The Plutonium Route:

8. The plutonium route is simpler, cheaper and more manageable than the uranium route described above, because plutonium (which does not occur in nature) is produced as a by-product in a uranium-fuelled reactor. It can be separated and recovered from the spent-fuel of the reactor by chemical processing because uranium and plutonium are two separate elements and therefore, are chemically distinguishable.

9. Wet Process: Essentially, there are two chemical processes which are used to separate plutonium from the spent-fuel of a reactor. One is the wet process and the other is the dry process. The most proven and economic process is the solvent extraction process in which the highly radioactive spent-fuel elements of natural or enriched uranium discharged from a reactor, are chopped into bits behind heavily shielded walls and dissolved in nitric acid. By selective chemical treatment plutonium is separated in the form of a nitrate solution and then reduced into oxide or metal form as required. Incidentally, apart from being highly radioactive, plutonium is a very toxic material to handle so that it is treated in "glove boxes" and not on ordinary laboratory benches.

10. Dry Process: The dry process is based on the principle of sublimation which enables a solid to vaporize without going through the liquid phase. The rate of sublimation or volatilization of uranium and plutonium being different, it is possible to separate the two by volatilizing the spent-fuel discharged from reactors.

III. NECESSITY FOR SAFEGUARDS

Spread of Nuclear Technology:

11. History of scientific development shows that what is secret today becomes an open book tomorrow and nuclear technology is no exception. Many countries will be forced to embark upon a nuclear power generation programme to meet the growing power requirements for which the fossil and hydro resources may not be sufficient or economical to exploit. In the industrially advanced countries the energy consumption has been doubling every ten years (i.e. at a rate of 7.2% per year) during the last three decades and the rate of growth of power consumption in developing countries of Asia, Africa and Latin America has been and will continue to be faster, because of the transitional stage of their economic development. The estimated generation of nuclear power in the nuclear-weapon and non-nuclear-weapon states up to 1985 is shown in Appendix III.

12. Some of the non-nuclear-weapon countries may try to become self-sufficient in supplies essential to their nuclear power programmes particularly in respect of nuclear fuel supplies. A self-reliant nuclear programme involves the establishment of the following facilities or plants for:-

(i) Mining the ores of uranium*,

(ii) Refining the uranium ores and converting them into "yellow cake" (U_3O_8) and from the "yellow cake" to reactor grade uranium oxide (UO_2) or pure uranium metal,

(iii) Fuel fabrication and cladding,

(iv) Research and power reactors,

(v) Fuel reprocessing or plutonium extraction, and

(vi) Separation of U-235 from U-238.

13. Some countries may have the industrial infra-structure to establish all or any of the above-mentioned facilities but others may have to depend upon the transfer of know-how and nuclear and conventional hardware from more industrially advanced countries. In fact, bilateral co-operation has been a feature of development and spread of nuclear technology so far and will continue to be so in the future as well.

Application of safeguards:

14. It will be assumed that a non-nuclear-weapon state has either built on its own, or through imported technology all the nuclear facilities mentioned above so that

* Note: Hereafter only the uranium fuel cycle will be discussed as the thorium cycle has not yet been fully developed but when developed would follow the uranium cycle.

the relevance of the application of safeguards to each of these facilities may be studied. Of course, if only the reactors and some of the auxiliary nuclear facilities are established and not all the plants (i) to (vi) mentioned in paragraph 12 above, as may well be the case in the initial stages of a nuclear programme, the safeguards could apply only to such nuclear facilties as may have been established.

15. Now, the key to the whole issue of safeguards is the prevention of the diversion of special fissionable materials to military purposes. As has already been explained, these materials are obtained only at the end of the uranium or the plutonium routes so that the question may be asked as to why safeguards should be considered for nuclear plants other than those for plutonium or U-235 separation? The answer is that it is not necessarily the end of the route but the route itself that has to be safeguarded because a country not having a plutonium or U-235 separation plant but only the reactors may surreptitiously send the spent-fuel elements containing plutonium for reprocessing to other countries having the reprocessing facilities for acquiring plutonium for military purposes. Similarly, uranium in ore or oxide form may be sent for separation of U-235 in a separation plant and the requisite quantity obtained for military purposes. A strict watch on the nuclear materials, therefore, becaomes a part of an effective safeguards system. In fact, a check on the diversion of nuclear materials or operation and maintenance of nuclear facilities requires an almost "cradle-to-the-grave" approach to a properly administered safeguards system. However, for a safeguards system to be acceptable, it should not only be effective but simple and economical to administer. It should further ensure that any process or product of a proprietory nature should not leak out as a result of the inspections of the nuclear facilities. To adhere to all these criteria may be difficult, if not impossible, unless there is good faith, confidence and trust between the administrators of safeguards and the authorities of the non-nuclear-weapon states concerned with the operation of the safeguarded facilities and materials.

IV. INDUSTRIAL ESPIONAGE

16. One of the serious objections to the submission of the nuclear facilities materials and equipment to the IAEA system of safeguards, is the fear of industrial espionage resulting from inspections of the premises and records of the non-nuclear-weapon state concerned. This apprehension does exist to a certain extent but only in respect of those nuclear facilities and materials which are in the process of development but hardly in the case of those which are based on "proven" concepts and "proven" technology. Thus, for all the nuclear facilities mentioned in para. 12 above, the question of industrial espionage can be discussed with reference either to "proven" or "developing" nuclear technology. It would be impossible to do this for each type of nuclear facility but for illustrative purposes it is proposed to discuss here the possibilities of industrial espionage relating to two of the most vital nuclear facilities, namely, the reactors and the reprocessing plants:

Proven Technology:

17. Reactors: A reactor has three basic parts, namely, (i) the fuel, (ii) the moderator and (iii) the coolant. Those power reactors which are "proven" and which are in commercial production and considered competitive with conventional thermal power stations fired with oil, gas or coal, have a certain combination of the fuel, the moderator and the coolant. There are, for instance, power reactors using natural uranium as fuel and heavy water as moderator and coolant. There are others which use natural uranium as fuel but graphite as moderator and gas as coolant. Then there are the power reactors which use enriched uranium as fuel and light as well as heavy water as moderator with either water or gas as coolant. Thus, technically speaking there is hardly anything in a reactor of proven concept which could possibly be a subject matter of "industrial espionage". In any case, for carrying out the obligations of inspection of a reactor under a safeguards system, be it bilateral or multilateral, the key information required by the inspectors is about the fuel inventory and the fuel burn up. For this purpose, it is essential to check (i) unused fuel in store, (ii) fuel in use at the time of inspection in the reactor core (iii) the spent-fuel discharged in the cooling pond (iv) the spent-fuel sent out for reprocessing, if any, and finally (v) the "burn-up" to which the fuel elements were subjected during the operation from time to time. For information on these essential points, the inspectors would need to look into log sheets, log books, charts recording burn-up and power output, calculations and formulae used to determine the burn-up and power generation and the layouts of spent-fuel ponds with identified fuel assemblies. The information

collected from charts and records could also be supplemented by that which can be recorded by sophisticated instruments to determine the isotopic composition of plutonium formed in the spent fuel elements. A great deal can and will be done in future with the development of automatic and computerized methods of detection and collection of the required data at pre-selected points so as to minimize the physical inspection by a team of inspectors. In all cases of inspection a test operation of the reactor in the presence of inspectors would help to verify the information collected. In short from what has been stated above, it is obvious that the fear of industrial espionage during inspections of a proven reactor is largely unfounded.

18. Reprocessing Plants: The most important thing in a reprocessing plant is to determine the input, the output, the losses incurred in reprocessing and the residue in the form of depleted uranium and fission products. Now, the estimate of the quantity of plutonium and its isotopic composition in the spent-fuel that is put into the reprocessing plant, can be determined with the help of the records of burn-up to which the particular batch was subjected to in the reactor. Sophisticated instruments could be used and further developed to determine this important information. The problem of reprocessing losses and output can only be tackled by agreement with the operators of the plant as this would be based on the concept and design of the plant. A test run in the presence of the inspectors could help to resolve any discrepancy between the records and the findings by the inspectors. In this approach there is hardly any danger of leakage of information of a proprietory nature or risk of industrial espionage by the inspectors administering the safeguards.

19. Other Nuclear Plants: What applies to the reactors and the reprocessing plants also applies to other nuclear facilities such as the fuel fabrication plants, the conversion plants and the isotope separation plants, based on proven concepts. The only difficulty in respect of these plants is that sufficient experience has not yet been gained in carrying out inspections at well defined points and stages of operation of these plants.

Developing Technology:

20. The problem of industrial espionage during inspection of nuclear facilities which are in the process of evolution and development is indeed complicated but not insoluble. Intensive research is being done in many countries to evolve new designs of reactors which a view to reducing their costs, for example, by eliminating the cost of fabrication of fuel elements by using uranium fuel in the liquid form or in the form of pellets embedded in compressed graphite balls or "potatoes".

Obviously, inspection of such reactors cannot be done on the standards adopted for reactors of proven types. Here the only possible data for inspectors to obtain would be a broad outline of the design and the main features of the concept of the nuclear facility concerned, to the extent that would not divulge any secret. In such cases the inspectors would have to be content with the basic information relating to the accountability of nuclear fuel used and disposed of in operation. The "burn-up" and the neutron flux measurements at selected points to be mutually agreed between the operators and the inspectors may further lead to a very satisfactory application of safeguards to such developing reactors. An accommodation by the inspectors in such cases cannot pose a serious danger leading to the diversion of fissionable material for military purposes in any appreciable quantities.

21. What applies to the developing types of new reactors also applies to the reprocessing plants producing plutonium and the separation plants producing U-235 based on processes not yet "proven". Researches are being done to develop cheaper and simpler processes of recovering plutonium and U-235, and there is little doubt that the efforts would ultimately succeed. Once such plants become "proven" and competitive, there would be no problems, because experts can sit down and evolve a safeguard system for them. It is only during the "unproven" stage of their development that inspection if not carefully done may lead to industrial espionage. Even here what the inspectors may require is the preliminary drawings of design, the outline of the concept involved, the ratio of the input of nuclear materials to the output of special fissionable materials produced and finally the extent of losses and wastage as estimated by the researchers and designers. In fact, as stated already a trial run can be demonstrated before the inpsectors to corroborate the information given in the log books and other records. Such an inspection could hardly lead to leakage of proprietory information or espionage detrimental to the interests of the country developing new methods, processes or techniques.

Protection of Secrets:

22. The extent to which the interests of a non-nuclear-weapon state in regard to industrial espionage are protected by the International Atomic Energy Agency (IAEA) will be clear from the following facts:-

(i) That no inspector can conduct any inspection unless his antecedents are first approved by the state concerned.

*(ii) That in implementing the safeguards an IAEA inspector shall not 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".

*(iii) "The Agency shall not publish or communicate to any state, organization or person any information obtained by it in connexion 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 connexion with safeguards, but only to the extent necessary for the Agency to fulfil 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".

23. From what has been stated above, it is clear that an exaggerated fear of industrial espionage on the part of the non-nuclear-weapon states and excessive anxiety to apply the safeguards with as much rigour to all nuclear facilities of proven or unproven design on the part of the nuclear-weapon states through the IAEA may wreck that amity of approach which is so essential to build up on either side in the larger interests of the fulfilment of the aims of the NPT.

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* IAEA Safeguards Document No. INFCIRC/66/Rev.1 dated September 12, 1967.

V. BILATERAL AND MULTILATERAL APPROACH TO SAFEGUARDS

24. Different countries are and will remain at different stages of nuclear development so that transfer of nuclear facilities as a whole or in parts in the form of equipment, and hardware and transfer of nuclear materials from one country to the other has been and will always be a regular feature of international life. Similarly, for sharing the nuclear know-how and making use of common facilities like the reprocessing plants, etc., there will be regional groupings of countries on a multilateral basis such as those of the six countries of Western Europe (France, Italy, Federal Republic of Germany, Belgium, Luxembourg and Netherlands), which are parties to the "Euratom" Treaty which came into force on January 1, 1959 and of the ten countries (United Kingdom, Ireland, Switzerland, Norway, France, Denmark, Netherlands, Turkey, Federal Republic of Germany and Belgium), under the auspices of the European Nuclear Energy Agency (ENEA) which came into existence on July 22, 1959. The aims and objects of such exclusive "clubs" can be and are in fact different. For example, the Euratom Treaty allows a member country to develop nuclear technology for any intended purpose so that it can use atomic energy both for peaceful as well as military purposes. In fact, France became a nuclear-weapon state after signing the Euratom Treaty.* Similarly, although the co-operation between the ENEA members is confined to the peaceful uses of atomic energy, it does not debar any member from being or becoming a nuclear-weapon state. The membership of the United Kingdom proves this. The only International Body that is devoted exclusively to the promotion of peaceful uses of atomic energy is the IAEA. Thus, today there is the co-existence of bilateral, regional and international arrangements for the development of nuclear energy. In these arrangements the issue of safeguards is also covered and it is this aspect of these arrangements which needs to be carefully examined.

Bilateral Agreements:

25. The safeguards provisions of a bilateral agreement can vary from a simple declaration of intention that the parties to the agreement would use the nuclear facilties and materials, covered by the agreement for peaceful purposes, to very severe and rigid provisions involving inspections on a reciprocal basis. Thus, the bilateral agreements between the countries A and B may be quite different in scope and extent to those between A and C

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* The first atomic bomb was tested by France on February 13, 1960.

or between countries D and E. Sometimes in order to sell a nuclear facility, the safeguards provisions may be considerably relaxed by a supplying country and at other times political considerations may soften the application of safeguards. There may in extreme cases even be a collusion or connivance which may enable a recipient country to acquire nuclear weapon technology. Judged, therefore, from purely the safeguards angle, bilateral agreements should conform to internationally accepted standard provisions. This can only happen if the non-nuclear-weapon states which are parties to such agreements volunteer to place all their nuclear facilities and materials under the control and administration of the IAEA, irrespective of whether they sign the NPT or not. In other words, there can be three categories non-nuclear-weapon of states: (i) those which sign the NPT, (ii) those which do not sign the NPT but volunteer to place the safeguards provisions of their bilateral and multilateral agreements under the IAEA and (iii) those which may neither sign the NPT nor agree to transfer their bilateral and multilateral provisions relating to safeguards to the IAEA. It is this last category of non-nuclear-weapon states and those industrially advanced countries among such states which have built their nuclear facilities without any bilateral or IAEA assistance, which would pose a serious problem to proliferation. It is such countries which raise the issue of sovereignty and industrial espionage, etc. The question of industrial espionage has already been dealt with separately in paragraphs 16-22 of this paper.

Multilateral Agreements:

26. What applies to the bilaterals, applies with equal justification to the regional arrangements under a multilateral organization, with this difference that members of the multilateral group could jointly as well as severally negotiate an agreement on safeguards with the IAEA under the provisions of its Statute. Thus, non-nuclear-weapon states parties to a multilateral arrangement could negotiate with IAEA even without signing the NPT in which case they would divide themselves into the same categories as those referred to in preceding paragraph. The negotiations with IAEA, in such cases, would require flexibility of attitudes on certain issues on either side because of the difference in approach of the IAEA and the multilateral organizations not only to the issue of inspections but also to the aims and objects of the organizations concerned. This is illustrated by comparison between IAEA, the Euratom and the ENEA which is given below:-

IAEA:

(i) The IAEA safeguards are not mandatory and are attracted only if a member-state requests for the assistance of the Agency or volunteers to place its nuclear facilities under the IAEA safeguards system or being a party to a bilateral or multilateral agreement may individually or collectively agree to the transfer of the safeguards provisions of such bilateral or multilateral agreements to the IAEA after negotiating an agreement with the Agency.

(ii) The IAEA safeguards system requires the submission of initial drawings and designs of the nuclear facilities to be safeguarded and applies not only to nuclear facilities and materials but also extends even to those nuclear facilities for which assistance is required for non-nuclear equipment, hardware and supplies provided they are considered as amounting to substantial assistance by the Agency.

(iii) The IAEA inspectors have access at all times to all the safeguarded facilities and materials.

(iv) The team of inspectors sent is composed of men approved in advance by the member-state whose facilities are to be inspected.

(v) In extreme cases a member-state, not fulfilling the obligations assumed, under the Statute of the Agency may lose the assistance of the Agency and be suspended from membership.

EURATOM:

(i) The Euratom Treaty requires the maintenance of accounts of the ores, the source materials and the special fissionable materials. The inspections do not apply to hardware, equipment or non-nuclear supplies.

(ii) Inspections are carried out by a multilateral inter-state team of inspectors by mutual agreement.

(iii) There is a provision for taking action against a member of Euratom, which refuses to reveal information to the inspection team.

ENEA

(i) The inspections envisaged under the security control arrangements of ENEA are fairly extensive, but are limited to co-operative arrangements between the members concerned for peaceful uses of atomic energy. There is thus no uniformity of procedures for inspection.

(ii) Penal provisions have been made for taking action against the violation of the security control by any member-State.

27. It will be seen from the above that negotiations which the non-nuclear-weapon states which are members of Euratom/ENEA would conduct with IAEA though delicate can be successfully conducted. There is wealth of experience in the system of accounting of nuclear materials which the Euratom system of inspections has helped to accumulate and there is considerable technical knowledge on the critical points and stages of nuclear facilities at which inspections should be carried out. The IAEA would do well to digest the information and techniques available with Euratom and modify its approach to the safeguards procedures which in absence of extensive inspections has been more theoretical than practical and realistic. On the part of the Euratom countries, the fear of industrial espionage for the reasons given in paragraphs 16-22 are more imaginary than real. In short, if there is a spirit of realism on both sides rather than a pedantic approach full of suspicions, the inspections under multilateral arrangements can easily be taken over by the IAEA. In fact, the Euratom/IAEA pattern of agreement under para. 4 of Article III of the NPT may well lead to the regional groupings in other parts of the world like Asia, Africa and Latin America.

VI. CONCLUDING REMARKS AND SUGGESTIONS

28. From this paper, the following concluding remarks and suggestions are made to help the Conference to study the issues involved in the application of safeguards and conduction of inspections under the IAEA system with particular reference to industrial espionage.

(i) That a peaceful nuclear programme need not necessarily lead to production of nuclear weapons. The plutonium produced in power reactors, even if separated, cannot be used for weapons as its isotopic composition is not favourable for such purposes. Weapon-grade plutonium have to be pure Pu-239 (90-95%) which can only be "bred" at very low burn-ups (See shaded portion in the graphs given in Appendix II) and these cannot be attained in power reactors unless the cost of power is heavily penalized. A simple inspection of burn-up record of fuel in any reactor can clarify this issue.

(ii) The rigours of safeguards, should not be applied to reactors as much as to reprocessing plants and isotope separation plants. If the reprocessing of spent-fuel could be done in plants either established under the sponsorship of the IAEA in a region for the convenience of a group of non-nuclear-weapon states or thrown open to the IAEA inspection wherever located, the problem of proliferation and fear of industrial espionage would disappear. It is estimated that about 5 reprocessing plants for the recovery of plutonium in the non-nuclear-weapon states during the life time of the NPT, would meet the reprocessing requirements of all such states.* The investment in these plants could be internationally financed and plutonium recovered from them sold on a commercial basis under the aegis of the IAEA.

(iii) All transactions of nuclear fuel between the nuclear-weapon states among themselves or between them and the non-nuclear-weapon states should be routed through the IAEA. The Statute** of the IAEA provides for such a role but it has not been activated as intended by the Statute. If the IAEA could manage a "fuel bank" as if it were, and charge a very small "brokerage" fee, the inspections could be easily financed by the Agency from this activity. The commission earned from brokerage would be a source of income to the Agency.

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* International Safeguards of a Chemical Reprocessing Plant, by T.C. Runion and B.G. Bechhoefer proceedings of the 1965 Conference on Atomic Industrial Forum Inc., Washington, D.C. (p.112).

** Article IX of the Statute of the IAEA.

(iv) The IAEA safeguards system should be simplified because the pre-NPT climate and attitudes are different from the post-NPT climate and attitudes. Simplicity of the IAEA system of safeguards should first be towards liberalization of exemptions in respect of simple items such as static neutron sources, non-nuclear supplies, hardware and equipment. Unless the system is simplified it would never be universally accepted.

(v) The key role entrusted by the NPT to the IAEA demands a thorough re-organization of the various organs of the Agency and its administrative set-up. As the Board of Governors of the IAEA is the executive body to approve or disapprove a request, accept or reject a point of view in regard to safeguards, the non-nuclear-weapon states should have a greater voice through the membership of the Board, more than half of which at present consists of permanent members* on a basis which has no relevance in the post-NPT period. Like other such Bodies of the specialized agencies of the United Nations the membership should be on a more democratic and enlarged basis.

(vi) The cost of administering safeguards can be considerably reduced by automation and computerized methods of detection of leakage of data. Intensive research to develop such instruments must be conducted so that fear of industrial espionage and cost of inspection may be reduced. The cost of research and inspections could perhaps be proportionately divided among the members of the United Nations or those of the IAEA pro-rata on the basis of the investment in the nuclear programmes or on the basis of the number of units of electricity generated by nuclear power reactors operating on the territories of the states which have embarked on a nuclear programme.

(vii) If any non-nuclear-weapon state desires to use peaceful nuclear explosives, the justification and economic feasibility of using them should first be determined by the IAEA before they are considered for supplies to non-nuclear-weapon states.

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* Present members are: Thirteen permanent, viz. Argentina, Australia, Canada, Czechoslovakia, France, India, Japan, Norway, Portugal, South Africa, U.S.S.R., U.K., and U.S.A., and twelve elected viz. Algeria, Brazil, Bulgaria, Ceylon, Federal Republic of Germany, Indonesia, Lebanon, Madagascar, Mexico, Peru, the Philippines and Turkey. (Vide Article VI of the Statute).

(viii) An International School of Inspectors should be established under the sponsorship of the IAEA to train the inspectors of various nationalities so that the fear of industrial espionage through inspections done by inspectors of certain nationalities may disappear. All IAEA inspectors should have had actual operating or maintenance experience of the type of the nuclear facility which they are deputed to inspect. This may be done by keeping a panel of part-time inspectors who may be working in their respective countries but whose services could be requisitioned to conduct inspections, in other countries, of facilities for which they have the requisite experience.

1. The Elements: All the tangible things whether in the form of solids, (like paper, pen or pencil), liquids (like water), or gases (like air) are all combinations of certain basic materials or substances called "Elements" of which only 92 are found in nature such as copper, iron, gold, uranium, hydrogen and oxygen, etc. Each of these elements has certain specific physical and chemical properties or characteristics by which it is identified.

2. The Atom: The last indivisible particle of an element having all the physical and chemical properties of that element, is called the "Atom". Thus, we have an atom of iron, an atom of gold and an atom of hydrogen, each having characteristics typically its own. If these elements are arranged in order of their weights in a Tabular form then Hydrogen, being the lightest, would occupy position No. 1 and Uranium, being the heaviest, would occupy position No.92. All others would fall in between these positions.

3. Atomic Structure and Atomic Particles: All atoms have internal structures which are built out of a combination of three fundamental "bricks" called the "Electron", the "Proton", and the "Neutron". The last two have more or less the same weight and size but the electron is about 1800 times lighter in weight. Further, the electron is electrically negative, carrying the smallest possible electric charge, while the proton carries a positive charge equal to the negative charge of the electron. The neutron carries no charge and is electrically neutral. Finally, the structures of all atoms are built in such a way that in the centre there is an inner core or a "Nucleus" which consists of protons and neutrons held together by a very strong binding nuclear force. Round the nucleus the electrons revolve in orbits just as the planets revolve round the sun in the Solar System.

4. Isotopes: Based on the above theory of atomic structure, it has been found that it is the number of protons in the nucleus (and, therefore, the number of electrons in the orbits) that determine the chemical properties of an element. The presence or addition of neutrons in the body of the nucleus does not cause any change in these properties. Thus, it is possible to have two atoms of the same element having the same number of protons in the nucleus but different number of neutrons. Both will have identical chemical properties but the nucleus of one would be heavier than the other. These are known as two "Isotopes" of the same element.

5. Radioactivity: Building up the structures of atomic nuclei by adding protons and neutrons, starting from hydrogen, the lightest, to Uranium, the heaviest, it is found that a stage comes when the piling of protons and neutrons causes instability and the nucleus begins to disintegrate by emitting radiations in the form of particles or rays; this pehnomenon is known as "Radioactivity" and the elements showing this phenomenon are known as radioisotopes.

6. Transmutation of Elements: According to the theory of atomic structure, one element differs from another element by the number of protons in the nucleus of the element. If this number changes either by radioactive decay or by bombardment with nuclear particles then a new element is formed. This transformation of one element into another is known as transmutation.

7. Fission: The German scientists Otto Hahn and Strassmann in 1938 found that when slow neutrons hit the nucleus of the radioisotope uranium-235 (U-235) the nucleus fissioned into two almost equal halves and there was a tremendous burst of energy. As early as 1905, Einstein had proved that Matter and Energy are interconvertible and that if somehow Matter could be destroyed, it would appear in the form of Energy and this interconvertibility will be governed by a very simple equation $E = Mc^2$ where E is the energy liberated, M is the mass converted and c is the velocity of light which is 186,000 miles or 300,000 km per second. Einstein's equation satisfactorily explained the phenomenon of fission observed in the experiments of Hahn and Strassmann. This led to calculations which showed that if one pound of U-235 could be fissioned it would liberate as much energy as 1400 tons of high grade coal.

8. Neutron Flux: It is defined as the number of neutrons passing per unit time per unit area of a plane normal to the direction of the beam.

9. Chain Reaction and Critical Mass: The fission of every atom of U-235 is accompanied by the liberation of energy as well as the release of two to three secondary neutrons from the disintegrating nucleus. These neutrons if slowed down by a "moderator", like graphite or water, could get absorbed by another atom of U-235 present in a piece of Uranium and cause another fission which in turn would release energy and two to three more neutrons and so on. Thus, a "chain reaction" can be set up and liberation of energy controlled by adjusting the absorption of secondary neutrons by inserting some material like boron or cadmium. The minimum mass of fissionable material like U-235 or Pu-239 which can support a chain reaction is called the "critical mass" of the material. A contrivance sustaining a controlled chain reaction is called a "Reactor".

10. <u>Nuclear Power</u>: Liberation of atomic energy once controlled in a reactor can be used to heat water which can produce steam which in turn can drive a turbine to generate electricity. Thus, a nuclear power reactor can replace a coal, oil or gas fired boiler of a conventional thermal power plant.

11. <u>Enrichment</u>: Enrichment means the ratio of the combined weight of the isotopes uranium-233 and uranium-235 to that of the total uranium in question.

12. <u>Burn-up</u>: Burn-up is a measure of the consumption of a given nuclear fuel (e.g. U-235, Pu-239, etc.) in a nuclear reactor. It is usually expressed in terms of thermal energy liberated per unit mass of spent nuclear fuel. It is commonly expressed in terms of MWD/tonne.

13. <u>Fusion</u>: Every nuclear reaction is accompanied by a release or absorption of energy. However, there are only two types of nuclear reactions which liberate an appreciable amount of energy per event. One is the fission of heavy nuclei, already explained and the other is the combination of two light nuclei to form a single nucleus; this latter process is called "fusion". The most familiar example of fusion energy is provided by the fusion of isotopes of hydrogen like deutrium and tritium forming heavier nuclei. Such reaction takes place only at very high temperature of the order of million of degree. So thermonuclear energy has been harnessed only for military purposes, viz. in the "hydrogen bomb". The exploitation of fusion nuclear energy under controlled conditions for peaceful purposes has so far presented very serious technical problems which are under investigation.

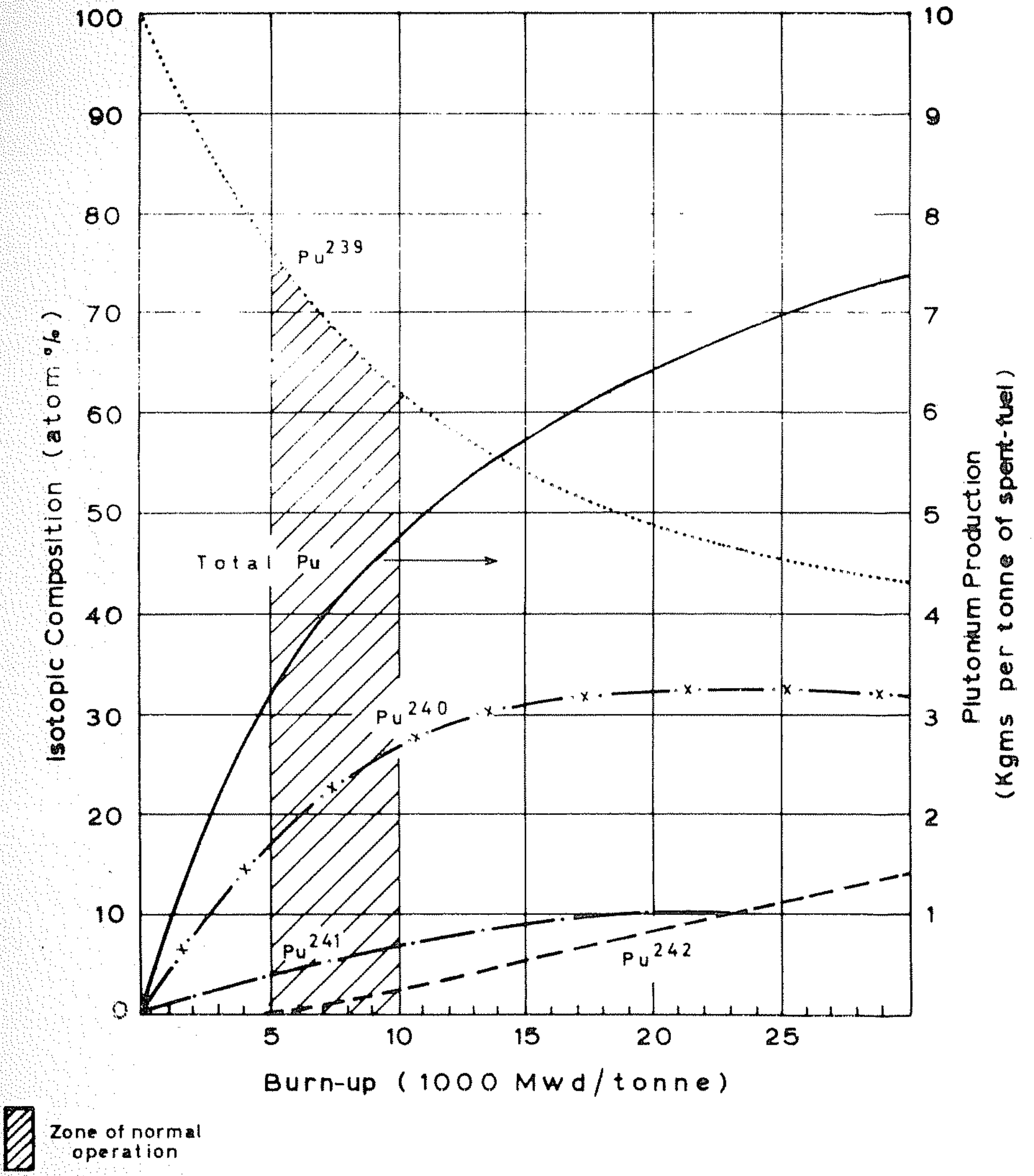
14. <u>Nuclear Material</u>; Nuclear material means any source or special fissionable material.

15. <u>Source Material</u>: Source material in turn means uranium containing the mixture of isotopes occurring in nature; uranium depleted in the isotope 235; thorium; any of the foregoing in the form of metal, alloy, chemical compound, or concentrate; any other material containing one or more of the foregoing.

16. <u>Special Fissionable Material</u>: Special fissionable material means plutonium-239; uranium-233; uranium enriched in the isotopes 235 or 233; any material containing one or more of the foregoing.

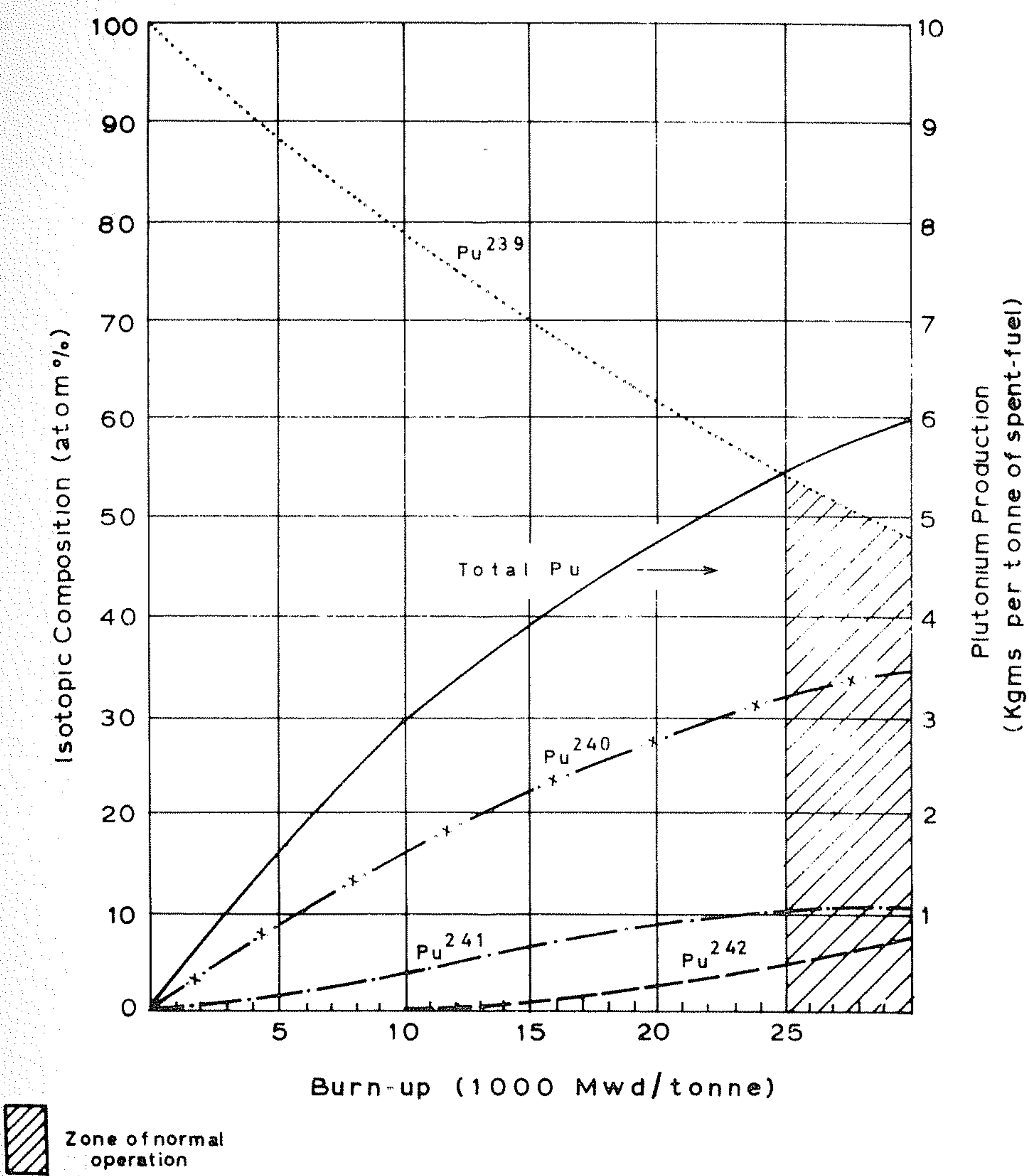
APPENDIX II

Fig(1) Plutonium Production in Natural Uranium Fuelled Heavy-Water-Moderated Reactors (HWR)



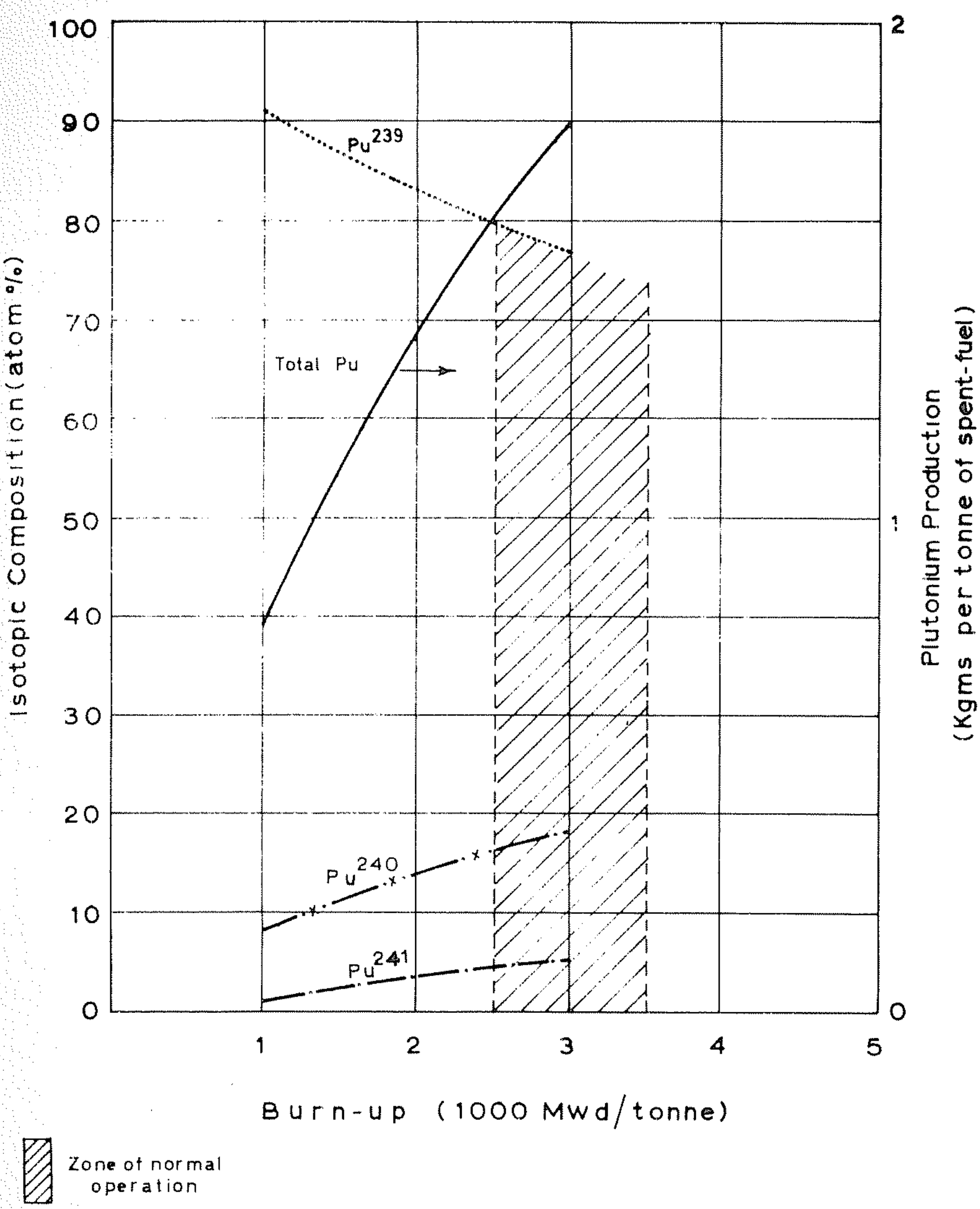
APPENDIX II (CONTD)

Fig.(2) Plutonium Production in Enriched Uranium Fuelled Light-Water-Moderated Reactors (PWR and BWR)



APPENDIX II (CONTD.)

Fig.(3) Plutonium Production in Natural Uranium Fuelled Graphite-Moderated Reactors (GCR)



ESTIMATED NUCLEAR POWER GENERATING CAPACITY UP TO 1985*

A. Nuclear-Weapon States:

(MWe)

Countries	Year				
	68	70	75	80	85
1. France	1,632	2,152	4,500	15,000	30,000
2. U.K.	4,757	5,597	13,300	25,000	45,000
3. U.S.A.	3,809	12,385	60,000	150,000	225,000
4. U.S.S.R.	1,167	1,215	1,815	4,000	8,000
Total (Nuclear-Weapon States):	11,365	21,349	79,615	194,000	308,000

B. Non-Nuclear-Weapon States:

(MWe)

Regions	Countries	68	70	75	80	85
North America	1. Canada	225	730	3,007	7,000	14,500
	Sub-Total:	225	730	3,007	7,000	14,500
Europe	1. Austria	-	-	300	800	1,600
	2. Belgium	10	10	1,210	2,100	4,100
	3. Bulgaria	-	-	800	1,500	2,500
	4. C.S.S.R.	150	150	480	900	1,500
	5. Denmark	-	-	500	1,500	3,000
	6. Finland	-	-	600	900	1,500
	7. Italy	600	600	1,232	8,600	16,600
	8. Netherlands	47	47	347	900	2,400
	9. Portugal	-	-	300	800	1,500
	10. Spain	153	1,543	2,793	4,900	9,900
	11. Sweden	141	541	2,241	4,000	8,000
	12. Switzerland	7	357	1,813	2,000	3,500
	13. West Germany	862	982	2,882	13,000	26,000
	14. Yugoslavia	-	-	300	1,000	2,500
	Sub-Total :	1,970	4,230	15,798	42,900	84,600

(MWe)

Regions	Countries	68	70	75	80	85
Asia	1. India	380	580	1,180	7,500	14,000
	2. Israel	-	-	300	900	1,900
	3. Japan	169	1,596	6,736	10,000	18,000
	4. Pakistan	-	137	337	1,500	3,500
	5. Philippines	-	-	300	700	1,400
	6. Turkey	-	-	-	-	400
	Sub-Total:	549	2,313	8,853	20,600	39,200
Latin America	1. Argentina	-	-	400	1,400	2,700
	2. Brazil	-	-	500	3,500	8,500
	3. Mexico	-	-	300	800	1,800
	Sub-Total:	-	-	1,200	5,700	13,000
Africa	1. South Africa	-	-	-	300	800
	2. U.A.R.	-	-	200	500	800
	Sub-Total:	-	-	200	800	1,600
Australia and New Zealand	1. Australia	-	-	200	700	1,500
	2. New Zealand	-	-	-	500	1,500
	Sub-Total:	-	-	200	1,200	3,000
	Total; (Non-Nuclear Weapon States)	2,744	7,273	29,258	78,200	155,900
	Grand Total: (World)	14,109	28,622	108,873	272,200	463,900

* (Explanation: The figures up to 1975 are mostly those given in "Power and Research Reactors in Member States" published by IAEA, in January, 1968. Beyond 1975, the figures are based on estimates by UKAEA (1966) and USAEC (1966). In cases of U.S.S.R., Bulgaria, C.S.S.R., and Finland, the IAEA figures have been extrapolated beyond 1975).