First Pugwash Symposium.Londra,11-16 IV 68.

1) - Programma.
2) - The production and control of nuclear energy and explosives.(C.F.Barnaby-J.Beckman)
3) - C.F.Barnaby:Development and control of the uses of atomic energy with particular reference to non-proliferation.
4) - D.Vital:Nuclear options and the long-term viability of a non-proliferation treaty.
5) - P.L.Olgard:TheUS-USSR draft treaty on non-proliferation.Will it work?

PROPOSED PUGWASH SYMPOSIUM ON:

"Control of Peaceful Uses of Atomic Energy with particular reference to non-proliferation"

to be held in the U.K., April 1968

Outline of programme:

1. Safeguards Systems

Methods of improving and expanding the IAEA safeguards system and the development of satisfactory long-term models of control procedures for future peaceful nuclear energy programmes with particular emphasis on the accuracy of control.

2. Control of Reactor-Exports

The development of an agreement between reactor exporting countries to only export reactors under the condition that the receiving countries would undertake to sell all the plutonium produced to an international organization with appropriate buy-back arrangements.

3. Control of Separation Plants

The possibility of placing existing plants under international control and controlling the development of gas centrifuges for the separation of U-235.

4. The Prevention of Proliferation

The incentives to persuade non-nuclear countries to sign a non-proliferation treaty including (a) guarantees to non-nuclear countries, (b) reduction of existing nuclear forces, (c) restrictions on development of new weapons systems, (d) technical aspects of inspection. Alternative policies to non-proliferation. The means of decreasing the prestige value of weapons as opposed to a peaceful nuclear programme.

5. Consequences of non-proliferation

Discussion of: commercial aspects; the reality of 'spin-off' of information; and the non-acceptability of civil applications of nuclear explosives.

6. Economic Aspects and Technical Aid

The limitation of reactor dissemination on economic grounds and the encouragement of alternative use of technical aid.

7. Political Aspects and Anti-proliferation Information

The means of counteracting arguments for retention of options to produce nuclear weapons and disseminating information on the consequences of nuclear proliferation.

8. International Political Aspects

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Long-term methods of reinforcing the non-proliferation treaty; the relationship between non-proliferation and the creation of non-nuclear zones; and the feasibility of creating a new and special status in international law extending the neutrality principle to nuclear weapons.

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FIRST PUGWASH SYMPOSIUM

"Control of peaceful Uses of Atomic Energy with particular reference to Non-proliferation"

LONDON, 11 - 16th April, 1968

C.F. Barnaby (U.K.)

J. Beckman (U.K.)

1 - 2

THE PRODUCTION AND CONTROL OF NUCLEAR ENERGY AND EXPLOSIVES

BACKGROUND PAPER

1. THE REQUIREMENTS

The heart of any nuclear armaments program, whether limited to fission bombs or directed toward producing the high temperatures needed to trigger fusion weapons, is the acquisition of a supply of one of three metals. They are Uranium-233; uranium having an atomic number 92(92 protons) and an atomic weight 233 (233 protons + neutrons), Uranium-235, having atomic number 92 and atomic weight 235, and Plutonium-239, having 94 protons and 145 neutrons (an atomic weight of 239). When any of these three types of atomic nuclei is penetrated by a neutron, the most probable result is a fission into several smaller nuclear fragments, with the release of energy and of more than one other neutron. It is possible to create a chain reaction in which the release of energy is explosive, provided that enough of the fissile metal is assembled to ensure that the emitted neutrons are all captured by other nuclei. Estimates for the critical masses, the minimum needed for an explosive reaction, are not difficult to make to within 50%, though officially still subject to security restrictions. The quantities are about 20kg. for U-235, less than 6kg. for Pu-239, and around 15kg. for U-233; any country which could obtain or manufacture quantities of this order in reasonable time would be in a position to move toward the "nuclear club".

Uranium-235 is found in nature mixed with its radioactive but non-fissile sister isotope U-238, as 0.71% of the total. Plutonium-239 and Uranium-233 on the other hand, must be produced from the naturally occurring U-238 and Thorium-232, respectively, by bombarding these metals with neutrons in a reactor; these two types of nuclei (nuclides) are termed "fertile". The nuclear reactions involved may be schematically written:

$$
\begin{array}{llll}
{}_{92}U^{238} + {}_{0}n^{1} \longrightarrow {}_{92}U^{239} + \gamma & & & \\
{}_{92}U^{239} \longrightarrow {}_{-1}\beta^{0} + {}_{93}Np^{239} & (t = 23.5 \text{ min.}) & & \\
{}_{93}Np^{239} \longrightarrow {}_{-1}\beta^{0} + {}_{94}Pu^{239} & (t = 2.3 \text{ days}) & & (1)
\end{array}
$$

$$
\begin{array}{llll}
{}_{90}Th^{232} + {}_{0}n^{1} \longrightarrow {}_{90}Th^{233} + \gamma & & & \\
{}_{90}Th^{233} \longrightarrow {}_{-1}\beta^{0} + {}_{91}Pa^{233} & (t = 23.5 \text{ min.}) & & \\
{}_{91}Pa^{233} \longrightarrow {}_{-1}\beta^{0} + {}_{92}U^{233} & (t = 27.4 \text{ day}) & & (2)
\end{array}
$$

The series of reactions (1) represents the production of Pu-239, and (2) the production of U-233. The times t are the half-lives of the spontaneous decay shown in their corresponding equations, the times for half the nuclei to undergo decay. The fact that one of the β-disintegrations, in which an electron is released, takes several days in each case determines the chemical cycling time in reactors where fuels are produced. When the fissile materials are produced, they are themselves unstable, decaying with the release of helium nuclei, α-particles, but with very long half-lives:

$$_{94}Pu^{239} \longrightarrow {}_{2}\alpha^{4} + {}_{92}U^{235} \quad (\ t = 24{,}000 \text{ years}) \qquad (1a)$$

$$_{92}U^{233} \longrightarrow {}_{2}\alpha^{4} + {}_{90}Th^{229} \quad (t = 162{,}000 \text{ years}) \qquad (2a)$$

but these spontaneous reactions are very slow compared with the average time for a fission in a typical reactor, so the loss of fissile material is negligible. To start a program of peaceful or military nuclear energy a supply of natural uranium, containing both the fissile U-235 and the fertile U-238 must be made available. As an alternative to U-238, Th-232 could be used as fertile material.

2. MINING AND EXTRACTION OF ORES

An outline scheme of the industrial paths by which nuclear fuels may be produced is shown in Figure 1. The scheme shows that those countries blessed with natural deposits of uranium are not immediately in a position to divert this to weapons production. The bulk of the world's easily accessible reserves of uranium ores, in the form of uranium oxide U_3O_8 , totalling between four and five million tons, has been located in the intensive prosp cting period of the late 1940's and the 1950's; this is the material which can be extracted at less than 10 dollars per pound of U_3O_8. There is no major difficulty in extracting the uranium from its ores, well-known methods for extracting metals, such as leaching with carbonates, cyanide, or sulphuric acid, and ion exchange matrix techniques being widely applied. As well as the well-known major producers, the U.S., Canada, South Africa, and the U.S.S.R. it is estimated that countries which could produce more than one tonne of uranium metal per year at a cost less than twice that in the major mining suppliers include Portugal and Sweden, with capacities grater than 10 tonnes per year, India, Argentina, Spain Japan and West Germany, with between 1 and 10 tonnes, also Egypt and Italy, which each have developed reserves estimated to contain over 500 tonnes in all.

Apart from the easy deposits which could be realistically developed on a commercial basis for a genuine power program, and these include large-scale thorium deposits in the U.S., India, and Canada, as well as smaller ones in Australia, Brazil, Madagascar and South Africa, a government determined on weapons development could utilize much poorer and therefore more expensive deposits. Low-grade bituminous shale and phosphate deposits contain 0.005 to 0.01% of uranium, as opposed to the 0.1% typical of the high-grade ores. The major low-grade world deposits comprise an estimated reserve of 20 million tonnes, of which 6 million lie in the Chattanooga shales of the U.S. Of more immediate interest is the low-grade uranium found in phosphates, because a commercially viable extraction plant could be developed in conjunction with fertilizer production. An estimated minimum of 600,000 tons of uranium metal, and about half that amount of thorium is contained in phosphate deposits.

Any uranium, and for most considerations of U-238 and its fissile derivative Pu-239 we can assume a close parallel with Th-232 and U-233, extracted and processed to give metal is not in a form needed for explosive purposes, even after passing through preliminary chemical purification stages. It is the following stages in each of the two major fuel paths shown in Fig.1 which are the key to weapons production. The uranium before these stages comprises 99.3% U-238 and only 0.7% U-235. It can be processed either chemically, to increase the proportion of U-235 sufficiently to make the fuel useful in power reactors, or processed directly in a reactor where the burning of the U-235 can release enough neutrons to convert some or all of the U-238 into Pu-239 which can then itself be burned. Of course instead of burning the fuels they could be diverted for weapons production.

3. FUEL ENRICHMENT

The building of an enrichment plant, to concentrate U-235 has been until recently a particularly massive technological investment. The difficulty

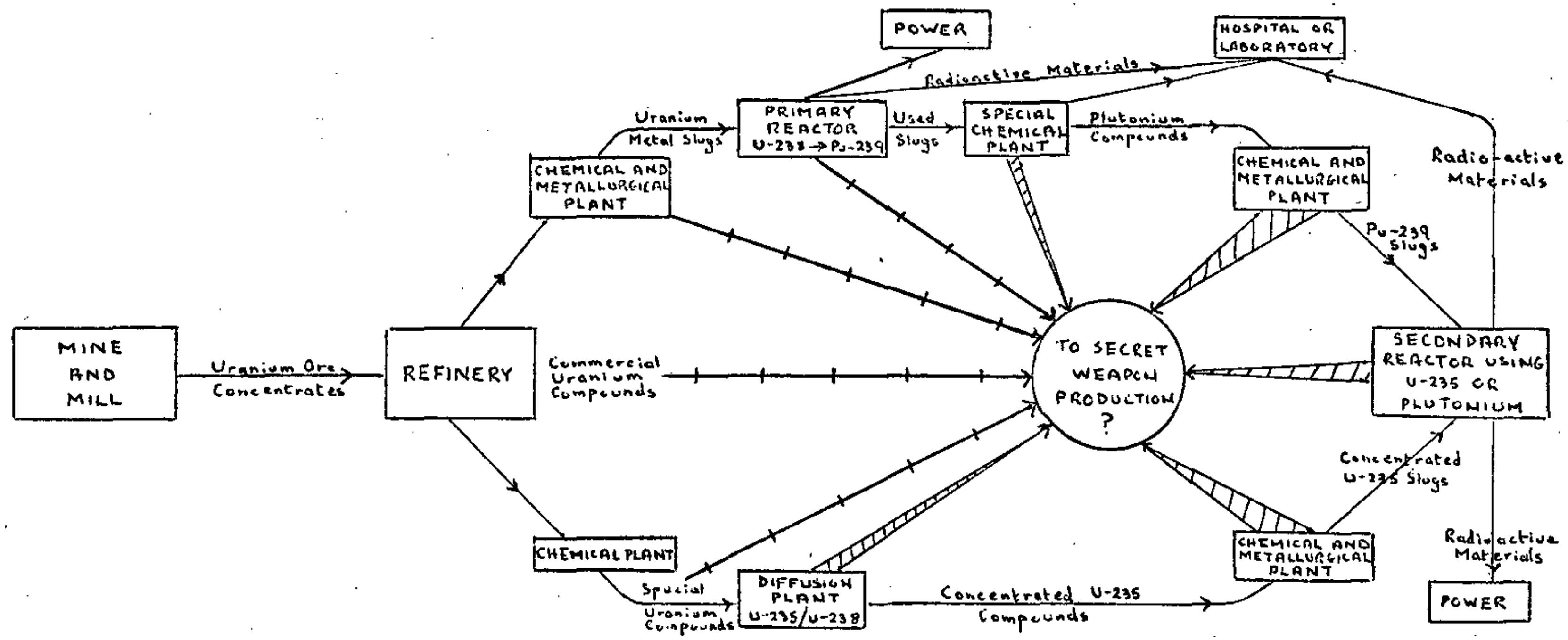

Fig. 1. Scheme of Processes using Uranium to produce Nuclear Energy or Weapons.

arises in separating two chemically identical isotopes, whose distinction lies only in their slightly different masses. The classical method, which was used during the war on the Manhattan project, and which is still the basis of the nuclear development of the major powers, is the method of diffusive separation. The uranium is passed, in the form of its gaseous compound UF_6, uranium hexafluoride, through a porous medium at high pressure. The medium is a partition in a chamber some 30 ft. long, which must be able to withstand high pressures without any leak whatsoever. The differential rate of flow of the two types $U^{235}F_6$ and $U^{238}F_6$ through the medium effects the separation. The maximum enrichment ratio per chamber is given by

$$y_1/y_2 = \alpha \ (x_1/x_2) \quad ; \quad \alpha = M_1/M_2 \qquad (3),$$

where the gas flowing out of the chamber is considered split into two streams, such that the ratio of U235:U238 in one stream is y_1/y_2 and in the other stream is x_1/x_2.

The value of α the enrichment factor per stage, is given by the square root of the ratio of the masses of the two component forms of UF_6. Its value is 1.00118, and in a practical case would fall even closer to unity. Estimates of the number of diffusion chambers needed to go from a U235 fraction of 0.7% to one of 94% give numbers between two and four thousand. The power needed to run such a chain is of the order of hundreds of megawatts; it is estimated that the Oak Ridge plant which first produced enriched uranium for atomic weapons consumed 250 megawatts. The nature of the porous medium which performs the separation is classified, but the French and almost certainly the Chinese have been able to develop the medium for use in their plants. However, the building and operation of an diffusion enrichment capability is clearly a major industrial undertaking, which could scarcely be concealed for long, and would not be undertaken lightly by a country with limited power resources.

The alternative form of enrichment plant using a high-speed centrifuge to separate the isotopes is distinguished by its potential economy of cost rather than of scale. Each separation stage comprises a high-speed centrifuge which separates particles on the basis of mass, in a precisely equivalent way to the centrifuge commonly encountered in the laboratory. The number of separation stages needed is measured in hundred, but the power requirements are much less severe. Because the development of the gas centrifuge separator is one of the greatest technical threats to non-proliferation it is sufficiently important to warrant a separate treatment.

4. REACTORS FOR FUEL PRODUCTION

A chemically much simpler route than that of enrichment is to use a reactor to provide fissile Pu-239 from U-238, and then to separate the plutonium chemically. The following brief outline of reactors should be of particular interest to non-specialists. The aim of a reactor is the controlled fission of U-233, U-235 or Pu-239 to give energy, neutrons, and smaller nuclei, the fission fragments. For power genration it is the most economical production of energy which is needed, and 1lb. of nuclear fuel provides the equivalent of complete combustion of 1500 tons of coal or 300,000 gallons of 100 octane liquid fuel, In the reactor the neutrons emitted during fission are allowed to bombard neighbouring nuclei, to cause these to split and maintain the chain reaction. As long as one neutron per fission can be used to promote another fission the reaction is self-sustaining.

4.1 Fissile Nuclides

To produce U-233 or Pu-239 as well as power, it is not only necessary to utilize one neutron for powers, but spare neutrons must be available for the conversion of Th-232 or U-238, the more abundant, fertile isotopes. These conversions are represented by equations (1) and (2). The question arises of how many neutrons are in fact released per fission;

Nuclide	α (No. of Neutrons/fissions)	$\alpha^{thermal}$ $\left(\frac{\text{Output } n}{\text{Input thermal } n}\right)$	α^{f} $\left(\frac{\text{Output } n}{\text{Input fast } n}\right)$
U-233	2.51	2.28	2.4
U.235	2.47	2.07	2.3
Pu-239	2.90	2.10	2.7

Table 1. Neutrons made available from fission processes.

The first column in the table indicates the number of neutrons released from the fission of the three nuclides involved; the second and third columns show how many neutrons would be produced for each neutron striking a fissile nucleus, taking into account the fact that each encounter does not necessarily split the nucleus, but might convert it in a manner similar to the processes shown in equations (1) and (2). The figures show that if one neutron per fission is used up to sustain the chain of reactions, and one is channeled into fertile U-238 or Th-232, to produce more fissile material, there will still be a small remainder to balance any inevitable losses. Reactors are designed to minimize losses but also to ensure that the chain reaction does not become explosively fast.

4.2 Moderators.

The three fissile nuclides are most susceptible to fission by thermal neutrons, that is by those moving at similar speeds to molecules at room temperature, which is slow compared to the speeds at which they are emitted from the disintegrating nuclei. Their energies are, when thermal, 0.1 electron volts, or less. Intermediate, or epithermal neutrons have energies from 0.leV to 50 Kev, and fast neutrons have energies greater than this. In order to slow theemitted neutrons to thermal speeds substances known as moderators are used. These remove energy from the neutrons by simply scattering them elastically. Elements of low nuclear mass, that is of low atomic weight have the best moderating properties, as their own recoil momentum is greatest, so that they absorb most energy. Thus water (H_2O) containing hydrogen, heavy water (D_2O) with deuterium, and beryllium and carbon are useful moderators, but other nuclides of low mass, lithium and boron which react with neutrons are not useful.

4.3 Burner Reactors.

The simplest type of reactor, the burner, consumes the U-235 in either natural or enriched uranium, or burns Pu-239, without producing any further fuel by conversion using its spare neutrons. Such a reactor would have an active core of fuel, the fissionable nuclide, producing energy, surrounded by a moderator. A neutron-reflecting shield surrounds the core, and the energy is removed by a coolant in flow contact with the fuel. Such a coolant might be liquid water, which could be turned into steam to drive a turbine. Other possible coolants are liquid sodium, or sodium/potassium mixtures, organic compounds of very high boiling point, air, and CO_2 gas. In designing a reactor primarily to deliver power , nuclear processes can give a much higher temperature, and hence a much higher thermodynamic efficiency than conventional burning. The limitations are on the rate at which the coolant can remove energy, and the thermal stresses in the fissile material and its metal containers.

In order to control the fission rate, which is directly proportional to the concentration of neutrons in the fuel, rods of a neutron absorbing "poison" such as boron, or cadmium, or hafnium or gadolinium oxides are used. None of these materials, or the coolants or moderators described above poses problems of manufacture too great for a country wishing to set up a nuclear power or weapons industry. In particular heavy water, the subject of much secrecy during thelatter stages of World War 11, is now more readily available. It is the only type of moderator for certain important types of reactor, and must be separated from ordinary water, of which it forms one part in 6,700 naturally, by methods analagous to those described for U-235 enrichment. As the mass ratio of D:H is 2:1, by choosing compounds of as low as molecular weight as possible, ideally using D_2 and H_2 themselves, from electrolysis, the enrichment factor for this separation can be made much more favourable than in the case of UF_6, and the power required to produce deuterium on a commercial scale is much less than that for uranium enrichment.

4.4 Critical Mass.

The larger the mass of nuclear fuel in a reactor, the fewer the neutrons which can escape, per unit mass. The mass at which a reactor "goes critical" engendering a self-sustaining chain of fission, varies with the geometry, and the enrichment of the fuel. For instance a uranium salt with 90% U-235 would need only 1kg of U-235 to go critical, but if the U-235 is mixed in natural proportions with U-238, 200kg is needed in a mass of 30 tons of uranium, assuming a graphite moderator. If water were used as a coolant, so effective are its own neutron absorbing, as well as moderating properties, that no amount of U-235 in the form of natural uranium could exceed the critical mass. In an actual reactor more than the critical amount of fuel must be fed initially into the core, and control rods of poison are inserted to absorb the excess neutrons. As the fuel burns away the rods can be withdrawn, or are themselves made of burnable material which is consumed during the neutron capture at an appropriate rate.

The mainstream of power reactors at present used in the programs of the nuclear nations are CO_2- or water-cooled grphite-or heavy-water- moderated burner reactors, in which up to 3% of the initial U-238 is burned. As only 0.7% was originally present as fissile uranium, it is clear that a good measure of conversion of U-238 to Pu-239 can be achieved, and indeed such reactors are the main present-day source of weapons-grade plutonium. A burner reactor can in fact use either enriched fuel, which is nevertheless not sufficiently enriched for use as effective nuclear explosive; it can then be water moderated, or it can use non-enriched fuel, which is partially converted to separable weapons-grade Pu-239, but needs heavy water or very pure graphite on a large scale for moderation. By charging a 12% rent on heavy water stocks, and only 4% on enriched uranium, the AEC of the U.S. has tried to prevent the spread of Pu-239 production in burner reactors.

4.5 Breeders.

It is not the burner, but in the long run the breeder reactor which is potentially the most productive source of Pu-239 or U-233 for weapons. The neutrons emitted from a fission process are fast. If a reactor has no moderator, it is termed a fast reactor, and fuel for such a reactor must contain at least 25% of a fissionable nuclide, because the susceptibility of the other nuclei to fission by fast neutrons is lower than for thermal neutrons, so one can afford to let fewer escape. The rest of the material in the reactor core must be of high nuclear mass, to prevent moderation by elastic scattering, and must not present a large cross-section for neutron absorption reactions other than fission. This rules out water for cooling, and sodium or potassium or a mixture is used as a coolant, for their good moderating and thermal conducting properties. The reflector surrounding the core could be of iron or of uranium, both with high mass numbers.

If there is fertile material either in the core or the reflector, it is possible by a suitable geometry to conserve sufficient neutrons to convert U-238 to Pu-239 at a rate equal to or greater than the rate of consumption of the initial U-235. This process can be made more efficient if Pu-239 is used as the initial fuel. The last figure in column 3 of Table 1. shows that for fast neutrons, 2.7 are available per disintegration of a Pu-239 nucleus compared with 2.3 and 2.4 for U-235 and U-233 respectively. The term "breeder reactor" was first applied only to those reactors producing the same fissile species as they consumed, but now a breeder is any converter producing at least as much fuel as it uses.

4.51 Fast Breeders.

The technical problems in designing a fast breeder reactor have been numerous and daunting. The fuel has to be held compact for good neutron economy but the ability to extract the heat produced calls for a dilute fuel. For the most economical working, which would not apply so powerfully to a non-clandestine weapons program. fuel elements must be found which do not require re-processing, that is having the plutonium separated from the fission products, until at least 20% of the fuel has been used. Metal elements which suffer radiation damage and would disintegrate may not be used, so uranium oxide is substituted, but this reduces the number of neutrons available per fission per unit mass. Finally control of the reaction is more difficult than with thermal reactors. This control, which aims at a high fission rate just thisside of an explosive one, is achieved using the small fraction of "delayed" neutrons from subsidiary reactions. For U-233 fission the fraction of delayed neutrons is 0.26%, for U-235 0.65%, and for Pu-239 0.21%. These are delayed by from 0.17 seconds to 55 seconds after the fission, and give just enough "friction" in the system to prevent runaway.

A diagram of a breeder reactor although it could depict graphically the description outlined above, can give little idea of the complexities of design, many of which are in any case subject to security restrictions. The size of the core, containing the fuel elements, is about that of a football. The coolant, liquid sodium, flows round the core and through the blanket of fertile material to transport heat to a steam generator for electrical power. The power density at the centre of a fast breeder is 4kw. per cubic inch, compared with 0.5 in a high-pressure naval boiler, 0.7 in a turbojet combustion chamber, and 35 in the chamber of an Atlas ICBM. The power density alone leads the engineering of a fast breeder reactor to be a major technical feat.

4.52. Thermal Breeders.

The alternative approach to breeding is a thermal one. Pu-239 is not susceptible to thermal breeding, because its neutron output to input ratio $\alpha^{thermal}$ is only 2.07 at thermal energies, which does not leave a margin for losses. The reaction can be made self-sustaining at epithermal energies, and this compromise also gives a lower power concentration, but has greater bulk and capital cost. The U-233 fission, with its value of 2.28 for $\alpha^{thermal}$ enables thermal breeding to occur; indeed U-233 can be used in breeders at all energies. The value 2.28 is really rather low, so it is almost imperative to use the best moderator D_2O, heavy water, and a suitable heat removal system to minimize neutron losses. These requirements have led to the development of the aqueous homogeneous thorium breeder, in which uranyl sulphate (the U-233 variety) in a dilute sulphuric acid solution, made up with D_2O, is pumped through a central "pot" where a critical volume is maintained. The circulating fluid is then pumped away through wider tubes to suppress the reaction.

Breeding occurs in a blanket of Th-232 surrounding the pot, and the subsequently separated U-233 can be fed into the aqueous solution to keep the conversion going. A further reason for using D_2O rather than water is that the low solubility of the uranium salt leads to an inefficient geometry. Initial difficulties encountered, of poor flow with local boiling which precipitated uranium from solution to burn holes in the pot, have now been overcome with a small-scale reactor at Oak Ridge. Because such reactors can in principle be made large, and since thorium is relatively abundant in low-grade ores, such as granite, the thermal breeder may well form the basis of much future nuclear power generation.

As far as weapons production is concerned, the initial charge of fuel for a thermal breeder must be highly enriched. This means that in the long term, there will be no guarantee that by supplying enriched fuel, a nuclear state may not be aiding a non-nuclear state towards weapons production, provided that the non-nuclear state can obtain a supply of thorium.

4.6 Some Reacter Design Considerations.

Metallurgical and materials developments take up much of the effort of nuclear technology. Fuel elements for both burners and fast breeders most conveniently comprise rods of uranium compound. For those reactors which cannot utilize water cooling because of the high neutron capture cross-section of its protons, either gas cooling, or liquid sodium cooling is used. Carbon dioxide and helium gases are not corrosive, nor do they obsorb neutrons, but they are not so efficient at heat transfer as water would be. This implies working at higher temperatures where fuel elements of uranium oxide would crack. No metal supports are available which can either resist cracking, or do not absorb neutrons. This has led to graphite supports and structures for gas-cooled reactors, which are however bulky, and involve high capital costs. Sodium cooling is more thermally efficient than gas cooling. In fact its potential for transporting heat from a reactor core has not been fully utilized. Uranium metal rods cannot go to extreme temperatures without swelling, and any attempt to restrict this with a metal sheath causes loss of neutrons. Uranium oxide does not swell, but does not deliver enough heat per unit mass to utilize the sodium cooling efficiently. Uranium carbide fuel elements combine the low expansion of the oxide with the thermal properties of the metal, and are under active development.

Fast reactors, with their concentrated cores require sodium cooling, but can afford metal sheathing for enriched uranium metal elements, since there is a more generous neutron supply. The metallurgical problems of processing enriched uranium, or plutonium for fast reactor fuel elements are severe, but the future use of such elements for breeding means that in this case also it will not be safe to supply enriched uranium for peaceful purposes when breeder technology becomes widespread.

So far we have seen that a country which can operate a separation plant for U-235 can produce fission weapons directly, while a country which can operate a large burner reactor can convert U-238 into Pu-239, starting from natural uranium. A breeder reactor, either fast or thermal, can be used to produce fissile material starting from enriched uranium or pure Pu-239. In the conversion cases, the Pu-239 or U-233 are produced embedded in a matrix of the original fertile species, together with up to 80 different fission products. The chemical methods of separation, which at one time might have been a barrier to weapons production, are nevertheless an order of magnitude easier and cheaper than isotope enrichment, and are susceptible to continual improvement.

When hundreds of nuclear power stations are operating throughout the world it is essential that safeguards systems operate in such a way that they interfere as little as possible with normal operational procedures and commercial practice. It has been suggested that the most essential control point is at the chemical separation plant. Ideally the plants should be operated by the International Atomic Energy Agency or under its close supervision. Alteratively, the separation plants should be inspected by the Agency under its safeguards system. The centres of distribution and use of enriched uranium should also be under IAEA control.

5. CHEMICAL PROCESSING OF FUELS

For power production the utmost economy is demanded in the chemical plant because significant loss of any fissile material here is as serious as loss of neutrons in the reactor proper, particularly for breeding. In a sense, the chemical processing is the key to the question of nuclear safeguards, because it is relatively difficult to conceal a diffusion plant or major reactor site and it is hard to imagine a country at present non-nuclear able to conceal such a major expenditure of power and research effort. Instead, while operating a far from clandestine reactor, the openly operated chemical plant could be so designed as to siphon off a small fraction of Pu-239, and at some future date possibly U-233, for weapons production. There is not enough space in this short outline to describe in any detail the separation plants now used. Although these have in the past used classical reagents in complex flow systems, the most recent ones have introduced ion exchange columns, which can separate out the plutonium from the uranium in a single solvent medium. As outlined in Fig. 2 the plutonium can then be purified in another ion column or series of columns, while the uranium is removed from the rest of the fission products by combining it with fluorine to give the gaseous hexafluoride in another branch of the system. Such a plant is neither expensive to construct nor very difficult to operate, although there are unusual problems for chemical engineers, those of handling radioactive materials. The simplification introduced by ion exchange can be seen by examination of Fig. 3 which is a simplified flow-sheet of an earlier approach to the separation of uranium, plutonium, and fission products; "Butex", is the organic solvent dibutyl carbitol. Although the 80 or so long-lived fission products are not specified in Fig. 2, the ion column used is specific to plutonium salts and takes care of the whole separation.

5.1 Chemical Safeguards.

It has been calculated that to safeguard a chemical plant well enough to check the plutonium output to within ±2%, a cost of $0.5 per gram would be added to the cost of Pu-239 as a fuel, whereas a realistic attempt to monitor the output to 0.2% would add $2.5 per gram, which is a quarter of the cost. It may be unreasonable to expect a country to bear the cost of the more thorough type of inspection, but the 2% level should be acceptable. If a 2% safeguard level could be made effective, it should place good limits on the short term weapons potential from diversion. Present estimates for burner reactors give a mean output of 0.2kg of plutonium per megawatt-year of electrical energy. To take the projected case of the West German power program in the year 1975, when a maximum of 10,000 megawatts may be installed; which would lead to 2000 kg. of Pu-239 per year, sufficient to give a 2% bleed-off amounting to 40kg. per year. This, while enough in principle for up to 8 weapons,

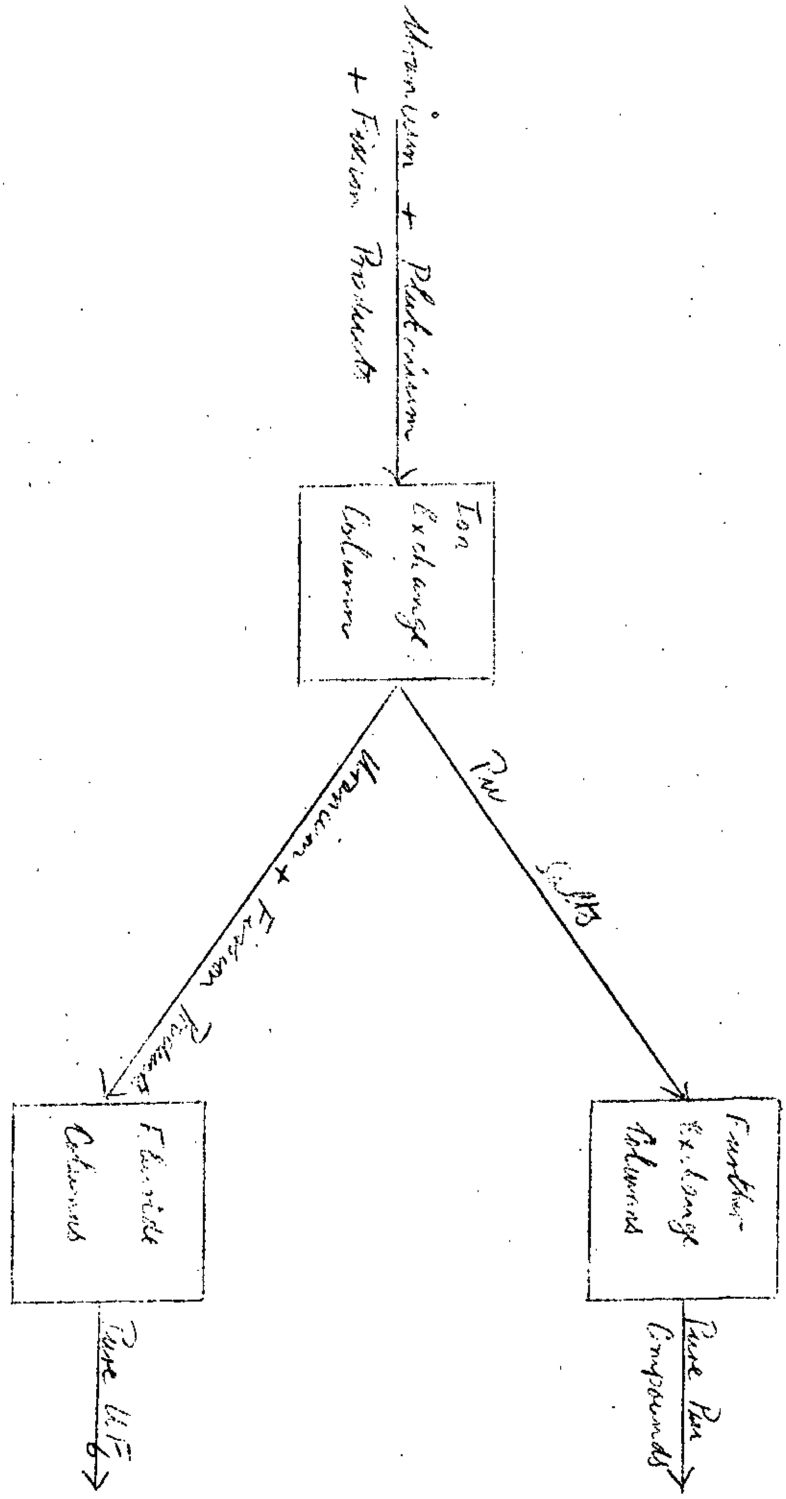

FIG. 2 **Simplified U-238/Pu-239 Separation Scheme**

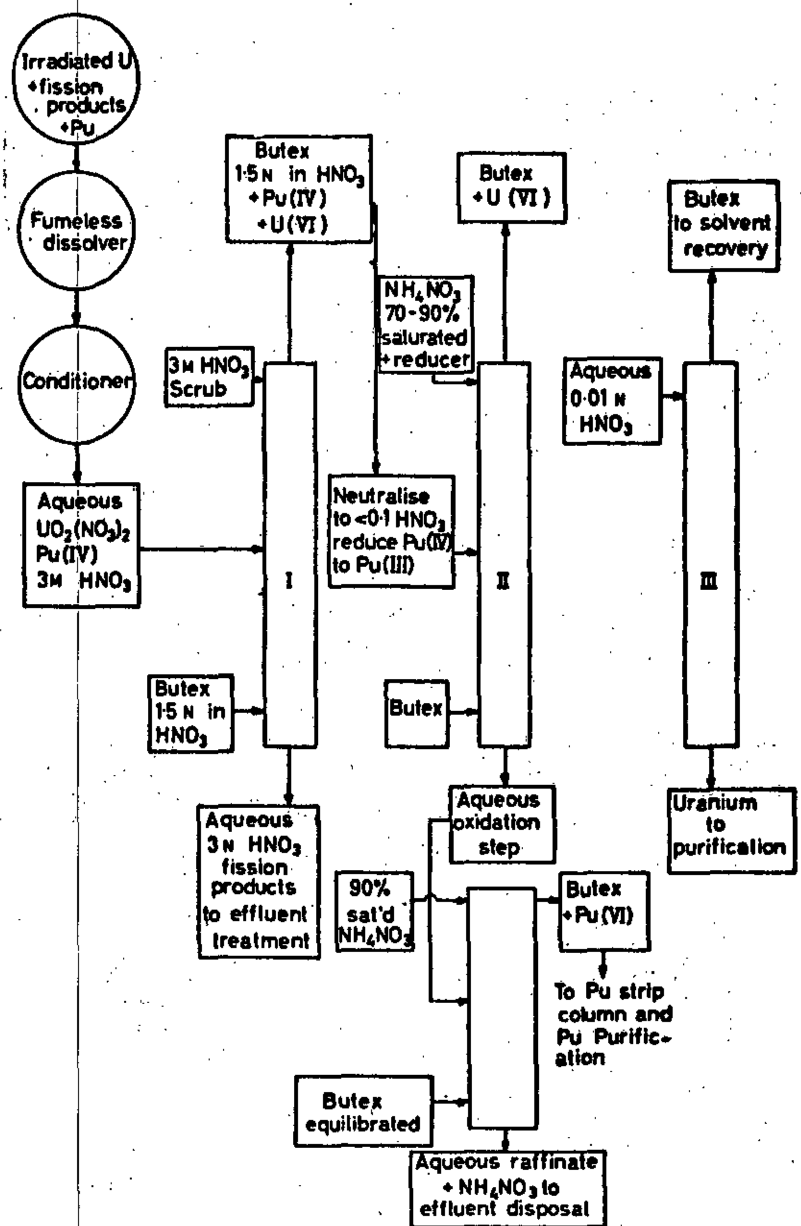

Fig. 3. Flowsheet of U/Pu Separation Plant

is the very maximum available, nor is any other non-nuclear power planning for a greater electrical capacity by that time. The situation will be entirely transformed when breeders are used in generating programs, when the plutonium output per megawatt-year will rise by at least an order of magnitude. For this reason the more serious short-term problem could be that of a small country which is prepared to cannibalize its power reactors to achieve a limited but more immediate cache of fission bombs.

6. CONTROL OF THE PEACEFUL USES OF ATOMIC ENERGY

6.1 Introduction

The above description of the complex technical processes involved in the nuclear energy industry indicates the difficulties inherent in devising an accurate safeguards system which would not significantly interfere with commercial practices or normal operational procedures. To indicate the measures established by the operating control systems each of them is now described in some detail.

The presently existing systems which attempt to provide international control of nuclear weapons are; the Western European Union; the European Nuclear Energy Agency; Euratom; the International Atomic Energy Agency; and the bilateral safeguards systesms of Canada, the U.K. and the U.S.A..

The object of all of these systesms and organisations is to secure international control, under international inspection, of weapons (typically nuclear) and warlike material (typically plutonium-239 and uranium-235); the systems are based on review of the design of facilities, visits by inspectors, the examination of operating records or control of the reprocessing of fuel elements

6.2 Western European Union

This regional settlement, largely military in character, was reached after the failure of the more far-reaching European Defence Community. The agreements which set up the W.E.U. in 1954 were signed by Belgium, France, the Federal Republic of Germany, Italy, Luxembourg, the Netherlands and the United Kingdom.

W.E.U. provided for a lesser degree of Western European integration than was intended in the E.D.C. plan but was designed to absorb a re-armed West Germany into Europe with a greater degree of control over the level of German forces and arms than could be achieved by N.A.T.O. Under the agreements West Germany renounced, until at least 1998, the production on its territory of atomic, biological and chemical weapons. West Germany also agreed not to produce missiles, sea mines, warships of over 3000 tons, submarines of over 350 tons, warships with non-conventional power and bombers. There were, however, conditions stated by which these restrictions could be varied.

France, Italy and Benelux agreed that when production of atomic, biological or chemical weapons had begun on their territories the levels of stocks they would hold was to be decided by the W.E.U. Council by a majority vote. The six continental countries (i.e. the seven minus the United Kingdom) further agreed to report to an Armaments Control Agency, established by the 1954 treaty on the major armaments held by their forces and also agreed that the quantities of these armaments should be approved by the W.E.U. Council. The Agency was to verify, by inspection, that the armaments restrictions were being observed.

The original settlement has been modified a great deal. West Germany, for example, is now permitted by the W.E.U. Council to make anti-aircraft and anti-tank missiles, to build a number of ships, previously prohibited, including submarines up to 450 tons of which six may reach 1000 tons.

No method of enforcing the restrictions has been worked out. The Council's powers when the 'effective production' of atomic, biological and chemical weapons has actually started are vaguely defined and, in the case of the French nuclear programme, have not been exercised. The Council claims that it 'has not received any notification' from France that effective production of weapons has started. The Treaty deems weapons grade plutonium to be an atomic weapon in itself. France began the production of this material in 1956 when her reactor at Marcoule started operation. Since then two more reactors have begun producing weapons grade plutonium, probably giving a total production of about 100kg. per year since 1959. Nuclear testing and the development and deployment of delivery systems continues. The Agency would, in any case, not be able to effect anything in the way of control since the Armaments Control Agency has been refused permission to recruit experts in nuclear weapons or to carry out inspections in the nuclear weapons field.

The Armaments Control Agency has been instructed to accept the levels actually reported by the relevant Governments as the appropriate levels. Its present activity is, therefore, mainly to check and confirm that the levels reported are accurate. The Agency has an international staff of about 50 persons and an annual budget of about £170,000. The Agency works by cross-checking budgetary and other data provided by member Governments and by the physical inspection of military installations, depots, shipyards, etc. The inspection covers levels of production and stocks of war material. In the case of Germany it is also supposed to confirm that no weapons prohibited by the Treaty are being produced.

The physical inspections are limited in scope and are of doubtful value. The Treaty requires that the inspections should not be routine but "in the nature of tests carried out at irregular intervals". Also it is required that the inspectors should be "accorded free access on demand to plants and depots". Neither provision has been met. France has not taken any steps to ratify the Convention (signed in 1957) which contains the necessary regulations and until this Convention comes into force the Agency is not authorised to carry out inspections in the way laid down in the Treaty. All it can do is to carry out so-called 'control exercises'. It asks the permission of Governments and private firms to visit installations, giving at least one week's notice. Such inspections are clearly not in accordance with the spirit of the Treaty.

The Agency has, however, carried out a series of experimental visits to a few laboratories and factories, which might be able to produce biological and chemical weapons, in West Germany and reported that no such weapons were being produced. Lack of qualified staff and authority prohibit it from doing the same thing in the nuclear weapons field. The 'control exercises' are completely inadequate. The Agency has the facilities and the power to inspect only a tiny proportion of all armaments subject to inspection and only a small number of installations capable of producing prohibited weapons could be visited to confirm that they were not producing these weapons. The Agency is clearly hamstrung by the Governments which formed it. Once the political obstacles to West German re-armament were removed the States of the W.E.U. showed little interest in applying the arms control provision of the 1954 Treaty to themselves.

The agreement enabling the W.E.U. Council to fix levels of forces and, within limits, the levels of conventional armaments has remained dormant. The Armaments Control Agency has been continually frustrated in its efforts to operate and both the Council and Governments have failed to apply the original intentions of the Treaty. France has consistently refused to allow its nuclear weapons programme to be inspected or even to declare the programme's existence to the Council. As the authority which ensures that the Treaties by which West Germany renounces the production of nuclear weapons, and certain other armaments, are obeyed the W.E.U. can claim to be successful but this is about the only success that it can claim.

The experience of the Armaments Control Agency has been of a largely negative character and limited to the cross-checking of budgetary and other statistical data; in this latter field however, valuable experience has been gained. Little has been learnt about the techniques of physical inspection and control.

The sections of relevant documents dealing with the control of nuclear weapons are now given.

<u>Protocol No. III on the Control of Armaments</u> (signed at Paris in October 1954, entered into force in May 1955)

<u>Part I</u> <u>Armaments not to be manufactured</u>

Article I The High Contracting Parties, members of Western European Union, take note of and record their agreement with the Declaration of the Chancellor of the Federal Republic of Germany (made in London on 3 October 1954, and annexed hereto as Annex I) in which the Federal Republic of Germany undertook not to manufacture in its territory atomic, biological and chemical weapons. The types of armaments referred to in this Article are defined in Annex II. These armaments shall be more closely defined and the definitions brought up to date by the Council of Western European Union.

Part II Armaments to be Controlled

Article 3 When the development of atomic, biological and chemical weapons in the territory on the mainland of Europe of the High Contracting Parties who have not given up the right to produce them has passed the experimental stage and effective production of them has started there, the level of stocks that the High Contracting Parties concerned will be allowed to hold on the mainland of Europe shall be decided by a majority vote of the Council of Western European Union.

Article 5 The Council of Western European Union may vary the list of types of armaments to be controlled.

Annex I The Federal Chancellor declares:

that the Federal Republic undertakes not to manufacture in its territory any atomic weapons, chemical weapons or biological weapons, as detailed in Annex II;
that the Federal Republic agrees to supervision by the competent authority of the Brussels Treaty Organization to ensure that these undertakings are observed.

Annex II This list comprises the weapons defined below and the factories earmarked solely for their production. All apparatus, parts, equipment, installations, substances and organisms, which are used for civilian purposes of for scientific, medical and industrial research in the fields of pure and applied science shall be excluded from this definition.

I. Atomic Weapons

(a) An atomic weapon is defined as any weapon which contains, or is designed to contain or utilize, nuclear fuel or radioactive isotopes and which, by explosion or other uncontrolled nuclear transformation of the nuclear fuel, or by radioactivity of the nuclear fuel or radioactive isotopes, is capable of mass destruction, mass injury or mass poisoning.

(b) Furthermore, any part, device, assembly or material especially designed for, or primarily useful in, any weapon as set forth under paragraph (a), shall be deemed to be an atomic weapon.

(c) Nuclear fuel as used in the preceding definition includes plutonium, Uranium 233, Uranium 235 (including Uranium 235 contained in Uranium enriched to over 2.1 per cent by weight of Uranium 235) and any other material capable of releasing substantial quantities of atomic energy through nuclear fission or fusion or other nuclear reaction of the material. The foregoing materials shall be considered to be nuclear fuel regardless of the chemical or physical form in which they exist.

Annex IV List of Types of Armaments to be Controlled

1. (a) Atomic,
   (b) biological, and
   (c) chemical weapons,

in accordance with definitions to be approved by the Council of Western European Union as indicated in Article I of the present Protocol.

Protocol No. IV on the Agency of Western European Union for the Control of Armaments (signed at Paris in October 1954; entered into force in May 1955)

Part I. Constitution

Article 1 The Agency for the Control of Armaments (hereinafter referred to as "the Agency") shall be responsible to the Council of Western European Union (hereinafter referred to as "the Council"). It shall consist of a Director assisted by a Deputy Director, and supported by a staff drawn equitably from nationals of the High Contracting Parties, Members of Western European Union.

Article 4.

1. The Director shall submit to the Council, through the Secretary-General, a plan for the organization of the Agency. The organization should provide for departments dealing respectively with:
- (a) the examination of statistical and budgetary information to be obtained from the members of Western European Union and from the appropriate NATO authorities;
- (b) inspections, test checks and visits;
- (c) administration.

2. The organization may be modified by decision of the Council.

Part II Functions

Article 7

1. The tasks of the Agency shall be:
- (a) to satisfy itself that the undertakings set out in Protocol No. III not to manufacture certain types of armaments mentioned in Annexes II and III to that Protocol are being observed;
- (b) to control, in accordance with Part III of the present Protocol, the level of stocks of armaments of the types mentioned in Annex IV to Protocol No. III held by each member of Western European Union on the mainland of Europe. This control shall extend to production and imports to the extent required to make the control of stocks effective.

2. For the purposes mentioned in paragraph 1 of this Article, the Agency shall:
- (a) scrutinize statistical and budgetary information supplied by members of Western European Union and by the NATO authorities;
- (b) undertake on the mainland of Europe test checks, visits and inspections at production plants, depots and froces (other than depots or forces under NATO authority);
- (c) report to the Council.

Article 9 The operations of the Agency shall be confined to the mainland of Europe.

Article 11 Inspections by the Agency shall not be of a routine character, but shall be in the nature of tests carried out at irregular intervals. Such inspections shall be conducted in a spirit of harmony and co-operation. The Director shall propose to the Council detailed regulations for the conduct of the inspections providing, inter alia, for due process of law in respect of private interests.

Article 12 For their test checks, visits and inspections the members of the Agency shall be accorded free access on demand to plants and depots, and the relevant accounts and documents shall be made available to them. The Agency and national authorities shall co-operate in such checks and inspections, and in particular national authorities may, at their own request, take part in them.

Part III Levels of Stocks of Armaments

Article 13

1. Each member of Western European Union shall, in respect of its forces under NATO authority stationed on the mainland of Europe, furnish annually to the Agency statements of:

(a) the total quantities of armaments of the types mentioned in Annex IV to Protocol No. III required in relation to its forces;
(b) the quantities of such armaments currently held at the beginning of the control years;
(c) the programmes for attaining the total quantities mentioned in (a) by:
  (i) Manufacture in its own territory;
  (ii) purchase from another country;
  (iii) end-item aid from another country.

2. Such statements shall also be furnished by each member of Western European Union in respect of its internal defence and police forces and its other forces under national control stationed on the mainland of Europe including a statement of stocks held there for its forces stationed overseas.

3. The statements shall be correlated with the relevant submissions to the North Atlantic Treaty Organization.

Article 20

1. The Agency shall immediately report to the Council if inspection, or information from other sources reveals:

(a) the manufacture of armaments of a type which the member concerned has undertaken not to manufacture;

Article 21 Each member shall notify to the Agency the names and locations of the depots on the mainland of Europe containing armaments subject to control and of the plants on the mainland of Europe manufacturing such armaments, or even though not in operation, specifically intended for the manufacture of such armaments.

Article 22 Each member of Western European Union shall keep the Agency informed of the quantities of armaments of the types mentioned in Annex IV to Protocol No. III, which are to be exported from its territory on the mainland of Europe. The Agency shall be entitled to satisfy itself that the armaments concerned are in fact exported. If the level of stocks of any item subject to control appears abnormal, the Agency shall further be entitled to enquire into the orders for export.

Convention concerning measures to be taken by member States of Western European Union in order to enable the Agency for the Control of Armaments to carry out its control effectively and making provision for due process of law in accordance with Protocol No. IV of the Brussels Treaty as modified by the Protocols signed at Paris on 23 October 1954 (signed at Paris in December 1957)

Chapter I Measures to be taken by Member States of Western European Union in order to enable the Agency for the Control of Armaments to carry out its control effectively

Article 1 Member States undertake to adopt the legislative measures or regulations required to secure the enforcement of the control measures taken by the Agency for the Control of Armaments (hereinafter referred to as "the Agency") in execution of Protocol No. IV to the Brussels Treaty as modified by the Protocols signed at Paris on 23 October 1954 (hereinafter referred to as "Protocol No. IV").

Chapter II Provision of Due Process of Law in accordance with Protocol No. IV

Article 3 A Tribunal located at the seat of the Court of the European Communities shall be established for the protection of private interests as contemplated by Article II of Protocol No. IV.

Section I Competence

Article 4

1. The Tribunal provided for in Article 3 shall determine claims for compensation against Western European Union submitted by physical or juridical persons whose private interests may have been damaged by excess or abuse of

authority on the part of the Agency or its officials, or by wrongful acts or omissions of such officials, committed in either their personal or official capacity and connected with the performance of their duties.

2. The Tribunal shall also determine claims for return of documents or other materials wrongfully obtained, made or detained by officials of the Agency in either their personal or official capacity and in connection with the performance of their duties.

Article 5 When reasons exist for considering that an irregularity of the kind contemplated in paragraph 1 of Article 4 has been committed, the Tribunal may, in exceptional circumstances, make a provisional order directing the payment into court of provisional damages. This order shall in no way prejudice the final decision of the Tribunal.
The Tribunal may in addition order measures of conservation, when the case involves documents or other materials obtained, made or detained by officials of the Agency.

Article 6 The decisions of the Tribunal shall, where appropriate, be based upon the Regulations for the functioning of the Agency as approved and officially published by the Council.

Article 7 If any person opposes or appears likely to oppose the execution of a control order, the Agency may, without prejudice to any penal liability which that person may incur, request a direction from the President of the Tribunal for the enforcement of access by officials of the Agency to the plant or depot or part thereof in question. The direction shall be made as speedily as possible when the President is satisfied that the control order is in conformity with the regulations referred to in Article 6. When the direction is made, the national authorities of the State concerned shall ensure access by the officials of the Agency to the aforementioned premises. Execution of this direction may not be prevented by any national authority, judicial or otherwise.
The decision of the President shall in no way prejudice the determination by the Tribunal of any subsequent claim concerning the same case submitted under Article 4.

6.3 The United States Bilateral System

The United States bilateral safeguards system, which arose from the Atoms for Peace Programme launched in 1953, anticipated the adoption of a more comprehensive international safeguards system. The development of bilaternal agreements was, therefore, a short term solution to the inspection problem. The first agreement for cooperation in civil uses of atomic energy was signed with Turkey in 1955 in which the transfer of nuclear material was limited to that required to fuel a research reactor and was, in any case, not to exceed 6kgs. of Uranium-235 contained in uranium enriched to a maximum of 20 per cent. Since then agreements have been signed with nearly fifty countries to which the United States has transferred: about 250,000 kg. of natural uranium; about 200,000 kg. of enriched uranium containing about 3000 kg. of U-235; some 70 kg. of plutonium; and about 800 tons of heavy water. These materials are used in facilities ranging from laboratories using small neutron sources (plutonium - beryllium) to large power reactors.

Following the Atoms for Peace Programme initiated by President Eisenhower in his address to the United Nations in December 1953 the United States Congress enacted the Atomic Energy Act of 1954. The sections pertaining to safeguards in this Act are:-

"Section 54. FOREIGN DISTRIBUTION OF SPECIAL NUCLEAR MATERIAL. - The Commission is authorised to cooperate with any nation by distributing special nuclear material, pursuant to the terms of an agreement for cooperation to which such nation is a party and which is made in accordance with section 123"

"Section 64. FOREIGN DISTRIBUTION OF SOURCE MATERIAL. - The Commission is authorised to cooperate with any nation by distributing source material and to distribute source material pursuant to the terms of an agreement for cooperation to which such nation is a party and which is made in accordance with section 123..."

Section 123 states that agreement for cooperation with foreign States shall contain a guarantee by the foreign State that any material transferred under the agreement shall not be used for nuclear weapons or for research on or development of nuclear weapons or any other military purpose.

The bilateral agreements of the United States with other Governments for cooperation for civil uses of atomic energy emphasize that any material, equipment or device made available to the Government pursuant to the agreement will be used for civil purposes only. The bilateral safeguards provisions closely follow the provisions proposed by the I.A.E.A. and contemplate a future assignment of safeguards responsibilities to the Agency - "the Parties will consult with each other to determine in what respects and to what extent they desire to arrange for the administration by the International Agency of those conditions, controls and safeguards required by the International Agency in connection with similar assistance...under the aegis of the International Agency".

The United States has the right under the agreements to review the design of facilities supplied by them and also the design of facilities using or processing nuclear or moderator materials so supplied. The receiving country must keep accountability and operating records and report periodically on these facilities. Maintenance of records and submission of reports are also required on nuclear and moderator material supplied by the United States and on material produced in facilities using such material or in facilities supplied by the United States. The United States has the right to conduct safeguards inspections on such material and facilities. Inspectors are to be accorded access to all places and data, and permitted to make any independent measurements as are necessary to account for the material subject to safeguards. The receiving country undertakes to facilitate the application of safeguards and guarantees that the foregoing safeguards will be maintained and that nuclear materials and facilities provided will not be used for nuclear weapons or for nuclear weapon research and development or for any military purpose. It is also guaranteed that the material and equipment will not be transferred outside the jurisdiction of the receiving country unless agreed to by the United States. In the event of non-compliance with the above safeguards requirements and guarantees the United States has the right to suspend or terminate the agreement for cooperation and to require the return of the nuclear material and equipment.

The United States Atomic Energy Commission maintains a division of International Affairs, consisting of a staff of seven personnel, to administer the safeguards contained in the bilateral agreements.

Implementation of safeguards may be undertaken whenever significant assistance is provided in the form of nuclear facilities, source materials, special fissionable materials, or any other assistance which has potential military use. The agreements also provide that components and materials, other than nuclear materials, may warrant safeguards. The receiving country is obliged to maintain records, submit periodic reports and permit inspections on this material.

The first trilateral agreement providing for the transfer to the Agency of the safeguards responsibility for nuclear materials and equipment supplied bilaterally was signed in September 1963 by the United States, Japan and the I.A.E.A. Under this agreement the Agency took over responsibility for United States-supplied nuclear material and facilities including eight reactors in Japan, their enriched uranium fuel and other special nuclear material being used in various research and development facilities. Fissionable material produced in these facilities is also safeguarded. This trilateral agreement has been followed by similar agreements with several other countries.

<u>6.31 United States - Euratom bilateral agreement</u>

In the bilateral agreement between the United States and Euratom the Community guarantees that no material, equipment or device supplied by the United States pursuant to the agreement will be transferred from the Community's control except by agreement with the United States. The Community has agreed to make its safeguards system compatible, within reason, with that of the International Atomic Energy Agency.

6.4 Euratom

Euratom is the organisation set up by the six countries of the European Economic Community (France, West Germany, Italy and Benelux) to build a Community nuclear energy industry for peaceful purposes. The Treaty establishing Euratom came into force on 1st January 1958. Euratom shares the European Parliament and the Court of Justice with the Common Market and the European Coal and Steel Community. It has its own Council of Ministers, each member represents one member State, and a five-man Commission which is independent of the member States.

Euratom coordinates research within the Community and promotes research in its own centres. It contracts specific tasks to national centres or firms and has joined international projects such as the European Nuclear Energy Agency project at Winfrith, United Kingdom (the Dragon project).

To develop the Community's nuclear energy industry Euratom has:

(a) formed a common market for all nuclear materials and equipment;

(b) established a low or suspended external tariff towards non-member countries;

(c) established a plan for the free movement, within the Community, for Atomic workers;

(d) introduced an insurance convention for large-scale atomic risks;

(e) established joint enterprises, of importance to the Community, which enjoy special privileges.

Euratom has nuclear cooperation agreements with Canada, United States and the United Kingdom. About 25 other countries have missions or delegations accredited to Euratom.

The European Atomic Energy Community

Chapter VII Safety Control

Article 77 Within the framework of this Chapter, the Commission shall satisfy itself that in the territories of Member States:
(a) ores, source materials and special fissionable materials are not diverted from their intended uses as stated by the users; and
(b) the provisions concerning supplies and any special undertaking concerning measures of control entered into by the Community in an agreement concluded with a third country or an international organization are observed.

Article 78 Anyone setting up or exploiting facilities for the production, separation or use of source materials or special fissionable materials, or for the processing of irradiated nuclear fuels, shall make a declaration to the Commission setting out the basic technical characteristics of such facilities to the extent that such information is necessary to the achievement of the purposes stated in Article 77.
The processes to be used for the chemical processing of irradiated material shall be subject to the approval of the Commission to the extent that is necessary for the achievement of the purposes stated in Article 77.

Article 79 The Commission shall require the maintenance and production of operating records in order to permit accountability for ores, source materials and special fissionable materials used or produced. The same shall apply to the transport of source materials and special fissionable materials.
Persons subject to such control shall notify the authorities of the Member State concerned of any communications which they make to the Commission pursuant to Article 78 and to the first paragraph of this Article.
The nature and scope of the obligations referred to in the first paragraph

of this Article shall be defined in regulations drawn up by the Commission and approved by the Council.

Article 80 The Commission may require that any excess of any special fissionable materials recovered or produced as a by-product, not being actually in use or ready for use, be deposited with the Agency or in storage premises which are or can be controlled by the Commission.

The special fissionable materials so deposited shall, at the request of the parties concerned, be returned to them without delay.

Article 81 The Commission may send inspectors into the territories of Member States. It shall, prior to the first visit of an inspector to the territories of any State, enter into consultations, which shall cover all future visits of this inspector, with the Member State concerned.

On presentation of their credentials, inspectors shall at all times have access to all places and data and to any person who by reason of his occupation deals with materials, equipment or facilities subject to the control provided for in this Chapter, to the extent necessary to control ores, source materials and special fissionable materials, and to satisfy themselves concerning the observance of Article 77. Inspectors appointed by the Commission 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.

In case of opposition to the carrying out of an inspection, the Commission shall apply to the President of the Court of Justice for a warrant to enforce the carrying out of the inspection. The President of the Court of Justice shall give a decision within a period of three days.

If there is danger in delay, the Commission may itself issue a written order, in the form of a decision, to the effect that the inspection be carried out. Such order shall be submitted without delay to the President of the Court of Justice for subsequent approval.

After service of the warrant or decision, the national authorities of the State concerned shall ensure access by the inspectors to the places named in the warrant or decision.

Article 82 Inspectors shall be recruited by the Commission.

They shall have the responsibility of obtaining and verifying the accounting mentioned in Article 79. They shall report any infringement to the Commission.

The Commission may issue a directive requiring the Member State concerned to take, within a period to be determined by the Commission, all necessary measures to terminate any infringement so found and it shall inform the Council thereof.

If the Member State does not comply with the Commission's directive within the time specified, the Commission or any interested Member State may, notwithstanding Articles 141 and 142, refer the matter to the Court of Justice immediately.

Article 83

1. In the event of any infringement of the obligations imposed on persons or enterprises under the provisions of this Chapter, penalties may be imposed on them by the Commission.

These penalties, in order of gravity, shall be as follows:

(a) a warning;

(b) the withdrawal of special advantages, such as financial or technical assistance;

(c) the placing of the enterprise, for a maximum period of four months, under the administration of a person or board appointed jointly by the Commission and the State having jurisdiction over such enterprise; or

(d) the complete or partial withdrawal of source materials or special fissionable materials.

2. Decisions of the Commission which require delivery in implementation of the preceding paragraph shall be enforceable. They may be enforced in the territories of Member States in accordance with the provisions laid down in Article 164.

Notwithstanding the provisions of Article 157, appeals brought before the Court of Justice against decisions of the Commission which impose any of the penalties provided for in the preceding paragraph shall have a staying effect.

The Court of Justice may, however, at the request of the Commission or of any interested Member State, order that the decision be enforced immediately.
The protection of injured interests shall be guaranteed by an appropriate legal procedure.
3. The Commission may make any recommendations to Member States concerning legislative provisions designed to ensure the observance in their territories of the obligations resulting from the provisions of this Chapter.
4. Member States shall ensure the enforcement of penalties and where applicable, the making of reparation by those responsible for any infringement.

Article 84 No discrimination shall, in the exercise of control, be made of the ground of the purpose for which ores, source materials and special fissionable materials are intended.
The field of action, the manner of control and the powers of the bodies responsible for control shall be limited to the requirements necessary for the achievement of the purposes stated in this Chapter.
Control may not extend to materials intended for the purposes of defence which are in course of being specially prepared for such purposes or which, after being so prepared, are, in accordance with an operational plan, installed or stocked in a military establishment.

Article 85 Where new circumstances so require, the manner of applying the control provided for in this Chapter may, at the request of a Member State or of the Commission, be amended by the Council acting by means of a unanimous vote on a proposal of the Commission and after the Assembly has been consulted. The Commission shall examine any such request by a Member State.

To obtain the necessary information for its safeguards system the Euratom Commission has issued two regulations; Regulation No. 7 and Regulation No. 8. Under Regulation No. 7 the Commission maintains a permanent inventory of nuclear installations and their capacities. It lays down the basic technical characteristics of the installation which must be declared to the Commission, i.e. all nuclear installations except mines. The Commission must be informed of the plans of installations, their capacity, the nature of the materials used and produced, the processes employed and the methods used to measure the quantity and quality of the materials held at the installations.

Under Regulation No. 8 the Commission is informed of the actual activities of the installations. This regulation applies to the system whereby the materials subject to safeguards in all installations except mines, are to be accounted for. It is stated that the enterprises are free to organise their own accounting methods as long as they are able to supply and verify the data required by the Commission. The data which must be submitted are those which are necessary to follow the movement and processing of nuclear materials in the six member States. Periodically the enterprises concerned must complete standard forms for the Commission on which is indicated the installation where materials are held, the quantities stored or in use, losses and movements to and from other Community installations or non-community States. The accuracy of the data supplied is checked by inspection.

6.5 The European Nuclear Energy Agency

The ENEA was formed to further the development of the production and uses of nuclear energy for peaceful pruposes by the participating countries, these are: Austria, Belgium, Denmark, France, Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and the United Kingdom. The Convention on the Establishment of a Security Council in the field of nuclear energy was signed in 1957 and ratified by all countries except Greece and Iceland. At the same time the European Company for the Chemical Processing of Irradiated Fuels (Eurochemic) was established in Mol, Belgium and was made subject to the control system.

The documents dealing with the establishment of the safeguards system of the ENEA, given below, explain the system reasonably clearly. The articles establishing the European Nuclear Energy Tribunal should be especially noted.

This Tribunal may consider appeals against decisions relating to the application of the safeguards system and decisions prescribing the sanctions which the Agency may impose under the Convention. The Tribunal may, on the other hand, order the Agency to make certain reparations for any unreasonable damage caused by the Agency, or its personnel, in the performance of their duties.

Convention on the Establishment of a Security Control in the Field of Nuclear Energy (Paris, December 1957)

Part I

Article 1

(a) The object of the security control is to ensure that
  (i) the operation of joint undertakings established by two or more Governments or by nationals of two or more countries on the initiative or with the assistance of the Agency and
  (ii) materials, equipment and services made available by the Agency or under its supervision, by virtue of agreements concluded with the Governments concerned

shall not further any military purpose.
(b) The security control may be applied, at the request of the parties, to any bilateral or multilateral agreement, or, at the request of a Government, to any activity for which that Government is responsible in the field of nuclear energy.

Article 2

(a) For the above purposes the security control shall apply to
  (i) any joint undertaking and to any undertaking which comes within the scope of an agreement concluded pursuant to Article 1 (a)(ii) or request made pursuant to Article 1(b);
  (ii) any facility using source materials or special fissionable materials recovered or obtained in such undertakings;
  (iii) any facility using special fissionable materials recovered or obtained either from source materials or from special fissionable materials subject to control by virtue of Article 1.

(b) Nonetheless, the Steering Committee of the Agency (hereinafter referred to as the "Steering Committee") may set aside the application of the security control where special fissionable materials are exported outside territory under the jurisdiction of Governments party to the present Convention, provided that these materials are subject to an equivalent security control.

Article 3 With respect to any undertaking or facility subject to control the Agency shall have the following rights and duties to the extent determined by the security regulations provided for in Article 8:
  (a) to examine the design of specialized equipment and facilities, including nuclear reactors, for the sole purpose of ensuring that the control can be effectively exercised as provided for in the present Convention;
  (b) to approve the means to be used for the chemical processing of irradiated materials solely to ensure that the object defined in Article 1 shall be achieved;
  (c) to require the maintenance and production of operating records to assist in ensuring accountability for source and special fissionable materials used or produced by the undertaking or facility;
  (d) to call for and receive progress reports.

Article 4

(a) Special fissionable materials recovered or obtained from source or special fissionable materials subject to control shall be used exclusively for peaceful purposes, under the control of the Agency, for research or in reactors specified by the Government or Governments concerned.
(b) Any excess of any special fissionable materials recovered or produced over what is needed for the above-stated uses shall remain subject to the control of the Agency, which may require it to be deposited with the Agency.

or in other premises controlled or which may be controlled by the Agency, provided that thereafter at the request of the parties concerned special fissionable materials so deposited shall be returned promptly to the parties concerned for use under the same provisions as stated above.

Article 5

(a) The Agency shall have the right and responsibility to send into Territory under the jurisdiction of Governments party to the present Convention inspectors, designated by it after consultation with the Government or Governments 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 subject to control, as necessary to account for source and special fissionable materials subject to control and to determine whether there is compliance with the obligations arising from the present Convention and from any agreement concluded by the Agency with the Government or Governments concerned.
(b) If these obligations are not observed, the Agency may request that the steps necessary to remedy the situation be taken; if this is not done within a reasonable time, the Agency may prescribe one or more of the following measures:
(i) the suspension or termination of deliveries of materials, equipment, or services supplied by or under the supervision of the Agency;
(ii) the return of materials and equipment supplied by or under the supervision of the Agency.

Article 6 The Governments party to the present Convention shall be responsible for carrying out the measures prescribed under paragraph (b) of Article 5 and by warrants issued by the President of the Tribunal under Article 11(e) and, where necessary, for ensuring that the parties responsible remedy any infringement.

Part II

Article 9

(c) Subject to their responsibility to the Agency, the inspectors and other members of the international personnel shall not disclose, even after termination of their employment, any facts or information which have come to their knowledge in the performance of their duties. Any contravention of this rule shall render them liable in any territory under the jurisdiction of Governments party to the present Convention to such penalties as may be in force in that territory for contravening the rules of professional secrecy, whatever may be the nationality of the offender.

Article 11

(a) Inspection shall be carried out by virtue of a warrant issued by the Control Bureau specifying the facilities to be inspected.
(b) In each case, the Government concerned must be notified in advance that the inspection is to be carried out, but such advance notification shall not indicate which facilities are to be inspected.
(c) The international inspectors shall be accompanied by representatives of the authorities of the Government concerned, if that Government so requests, provided that the inspectors shall not thereby be delayed or otherwise impeded in the exercise of their functions.
(d) The international inspectors shall also have the responsibility of obtaining and verifying the accounting referred to in Article 3(c), relating to source materials and special fissionable materials, and for ascertaining whether there is compliance with the obligations arising from the present Convention and from any agreement concluded with the Governments concerned. The inspectors shall report any infringement to the Control Bureau.
(e) Should a measure of inspection be resisted, the Control Bureau may ask the President of the Tribunal provided for in Article 12, for a warrant for the execution of the measure of inspection against the undertaking concerned. The President of the Tribunal shall give a decision within three days. The decision of the President shall not prejudice the determination by the Tribunal

of any subsequent claims concerning the same case which might be introduced later under Article 13.

Part III

Article 12

(a) There is hereby established a Tribunal consisting of seven independent judges appointed for five years by decision of the Council or, in default, by lot from a list comprising one judge proposed by each Government party to the present Convention.
(b) If the Tribunal includes no judge of the nationality of a party in a case submitted to it, the Government in question may choose a person to sit as additional judge in that case.
(c) The organization of the Tribunal and the status of the judges shall be in accordance with the provisions of the Protocol annexed to the present Convention.
(d) The Tribunal shall adopt its own Rules of Procedure, which shall be subject to the approval of the Council.

Article 13

(a) Any Government party to the present Convention or any undertaking concerned may bring before the Tribunal set up under Article 12 appeals against decisions:
  (i) relating to the application of Article 3; if no action has been taken within two months after the request for examination or approval, this is to be taken as a decision to reject the appeal;
  (ii) prescribing one or more of the measures provided for under Article 5 (b).
(b) When an appeal is brought before the Tribunal by virtue of the preceding paragraph, the Tribunal shall decide whether the decision appealed against is in conformity with the provisions of the present Convention, of the security regulations, and of the agreements provided for in Article 8. If it finds that the decision appealed against is contrary to these provisions the Steering Committee shall take whatever steps are needed to execute the decision of the Tribunal.
(c) The Tribunal may oblige the Agency to make reparation for any damage which might be suffered by the requesting party by reason of the decision appealed against.
(d) Any undertaking may, in addition, request the Tribunal to order reparation to be made by the Agency for any exceptional damage which it has suffered by reason of an inspection carried out in application of Article 5.

Part IV

Article 18

(a) The term "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; and such other fissionable material as the Steering Committee shall from time to time determine; but the term "special fissionable material" does not include source material.
(b) The term "uranium enriched in the isotopes 235 or 233" means uranium containing the isotopes 235 or 233 or both in an amount such that the abundance ratio of the sum of these isotopes to the isotope 238 is greater than the ratio of the isotope 235 to the isotope 238 occurring in nature.
(c) The term "source material" 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 in such concentrations as the Steering Committee shall from time to time determine; and such other material as the Steering Committee shall from time to time determine.
(d) The term "material" means source material and special fissionable material.

6.6 International Atomic Energy Agency

Since the details of the Agency's safeguards system ~~was~~ were given in the first background paper it will not be dealt with further here.

7. COMMERCIAL APPLICATIONS OF NUCLEAR EXPLOSIVES

It has been suggested by certain States (typically Brazil) that peaceful nuclear technology should not be regarded as a violation of any non-proliferation treaty if accompanied by a legal committment not to use the information obtained for making weapons and if international inspections were introduced.

Nuclear explosives have potential use for excavation project, natural gas stimulation, oil release, ore curshing and leaching, heat extraction and storage. In addition there are possible applications for scientific research purposes, for example in neutron physics. Some results have already been obtained.

In December 1967 the United States set off a nuclear explosion in the first such civilian project, sponsored jointly by the government (Atomic Energy Commission) and industry (the El Paso Natural Gas Company). A 26-kiloton nuclear device was exploded at a depth of 4240 ft. below the surface in the Leandro Canyon, New Mexico. The blast was designed to increase natural gas output by shattering a portion of the 285 ft. thick layer of gas-bearing sandstone lying beneath the Canyon; the gas is tightly locked within the rock. Normally gas is obtained by drilling a well into a formation of gas-bearing rock. The gas is forced through pores in the rock into the well casing by natural underground pressure. Producers then tap the large gas reserves with a relatively small number of wells. In many places, however, the natural gas is held in comparitively non-porous rock that prevents the flow of all but small volumes of gas into the wells. The wells are therefore expensive to drill and uneconomical to operate. Conventionally the flow of gas into the wells has been increased by forcing fluid under high pressure into the well or, alternatively, by underground explosions using chemical (non-nuclear) explosives. The resulting increase in the flow of gas through the fractures produced is usually shortlived and not worth the extra cost.

It is predicted by the United States Atomic Energy Commission that the recent nuclear explosion should have produced such extensive cracking that as much as 75% of the gas in the rock around the site of the explosion should flow into the well over a 20 year period, compared with about 10% which would be recovered by chemical explosive blasting.

It was calculated that the explosion should have formed a cavity in the earth, 160 ft. in diameter, and within about a minute after the detonation of the device the roof of the cavity would collapse inwards, forming a rubble-filled chimney about 250 ft. high. Pathways for the gas will be formed by cracks and fractures in the rock radiating out from the chimney over lengths of hundreds of feet.

Preliminary surveys indicate that the chimney did fill with gas but it will be several months before it is known whether the experiment will be successful. After this time a well will be drilled to the top of the chimney and gas freed by the nuclear explosion will be tapped off. Samples will be tested for radioactive contamination. It is hoped that the radioactivity will be low enough for the gas to be used commercially without much purification, which would be expensive. If the method is to be commercially viable the gas must also continue to flow into the well in volume. If this experiment proves to be a success it may stimulate many further subterranean nuclear explosions to tap natural gas now tightly locked beneath the earth's surface.

It has recently been announced that a consortium of United States and European countries is being considered to promote the peaceful

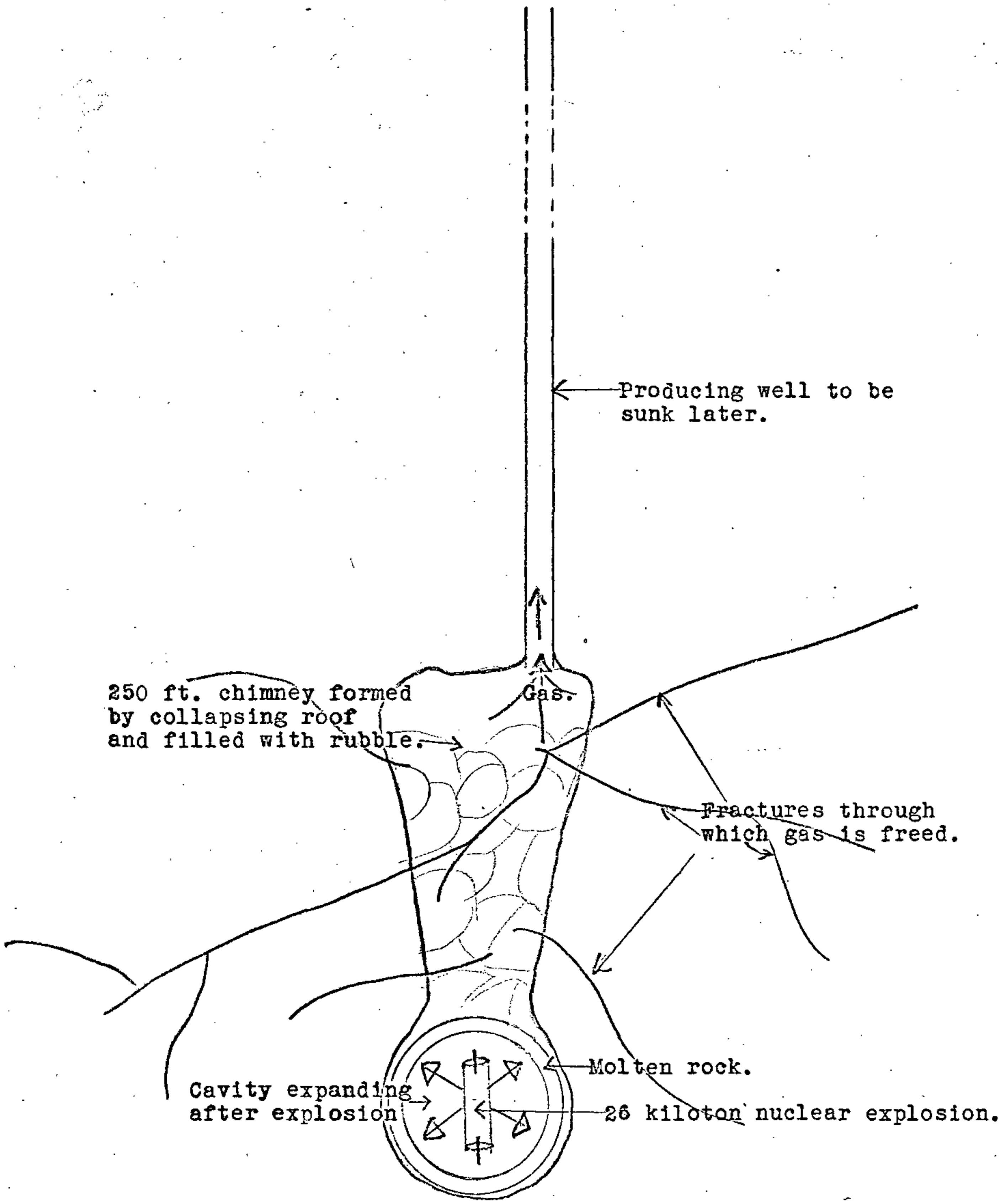

Fig.4 PROJECT 'GASBUGGY'.

applications of nuclear explosives. The group would be interested in such projects as: blasting canals; recovery of natural resources (natural gas, oil and metals); and building harbours and dams.

The main shareholders are the El Paso Natural Gas Company of the United States, the Société Nobel-Bozel of France and the Belgian firm of Poudreries Réunies de Belgique. It was stated that the groups concerned had signed a letter of intent and the new company, the Nobelpaso Geonuclear, would be formally established in March 1968. The company, half American and half European, would have its headquarters in Europe, probably in Belgium. Another French company and a West German company (Dynamit Nobel) are negotiating for inclusion.

Many experimental underground explosions have taken place in the United States and in Russia to investigate the potential use of nuclear explosions for commercial applications. Some of these have accidentally released readioactivity into the atmosphere.

System	Effective Date of Commencement	Legal Basis	Application	Present Status	Remarks
United States Bilateral System	1954	U.S. Atomic Energy Act of 1954 and bilateral agreements	Applies to bilateral agreements between U.S. and about 30 other countries. Safeguards over U.S. contributed materials to Common Market members are replaced by Euratom system.	In process of being transferred to the IAEA. The first trilateral agreement was signed in 1963, since then several more have been completed.	About 700 inspections have been carried out so far. U.S. does not inspect the uses made of materials and equipment supplied to EEC, U.K. or Canada.
Western European Union	1957	Convention, signed at Paris December 1957, to enable Armaments Control Agency to carry out its control in accordance with Protocol IV of the Brussels Treaty 1948 as modified by the Protocols signed in Paris, Oct. 1954	Convention has not been ratified by France. France has not reported to the Agency the development of its nuclear weapons. The provisions on nuclear weapons do not apply to the U.K.	Unsuccessful in control of nuclear weapons. The only success of WEU is as watchdog of treaties by which West Germany renounces the manufacture of nuclear weapons.	Seven European countries belong to WEU: France, Italy, West Germany, Benelux and U.K.
European Nuclear Energy Agency	1957	Convention on the Establishment of a Security Control in the Field of Nuclear Energy, signed at Paris, December, 1957.	Convention ratified by Austria, Benelux, Denmark, France, West Germany, Ireland, Italy, Norway Portugal, Spain, Sweden, Switzerland, Turkey, U.K. (Greece and Iceland are members of ENEA but have not ratified the convention).	Threatened with redundancy in that it occupies the middle position between Euratom and IAEA systems	ENEA has created a fuel processing plant (Eurochemic) at Mol, Belgium under controls.
European Atomic Energy Community	1958	Chapter VII (Safety Control) of the Treaty establishing the European Atomic Energy Community, signed at Rome, March, 1957 (came into force January, 1958).	Applies automatically in participating countries (France, W. Germany, Italy and Benelux) to all nuclear installations and fuels not already in nuclear weapons or clearly destined for them.	As a regional system has proved reasonably satisfactory. Euratom has agreed to make its safeguards system reasonably compatible with that of IAEA.	About 600 inspections carried out so far. Receives about 400 inventories and balance sheets giving details of raw and fissile materials in about 140 installations.

System	Effective Date of Commencement	Legal Basis	Application	Present Status	Remarks
International Atomic Energy Agency	1961 revised 1965	Statute of the IAEA, Article XII, July 1957. Revised safeguards system approved in 1965	The only potential universal system. The Agency has 98 members. Safeguards apply to installations in 29 countries.	The installations at present under safeguards represent only about 8% of the present nuclear power output.	The U.K. and U.S.A. have submitted some reactors to Agency safeguards. The Statut provides for the ultimate sanction of appeal to the U.N. General Assembly and Security Council in case of violation of any safeguards agreement.

Comparison of existing Safeguards Systems

FIRST PUGWASH SYMPOSIUM

"Control of Peaceful Uses of Atomic Energy with Particular Reference to Non-Proliferation"

6 - 11

LONDON, ~~11~~ - ~~16~~th April, 1968

C. F. Barnaby (U.K.)

J. Beckman (U.K.)

1-2a.

Amendments to Background Paper 1 - 2 entitled

THE PRODUCTION AND CONTROL OF NUCLEAR ENERGY AND EXPLOSIVES

2. MINING AND EXTRACTION OF ORES - paragraph 3

Any uranium, and for most considerations of U-238 and its fissile derivative Pu-239 we can assume a close parallel with Th-232 and U-233, extracted and processed to give metal is not in a form needed for explosive purposes, even after passing through preliminary chemical purification stages. It is the following stages in each of the two major fuel paths shown in Fig. 1. which are the key to weapons production. The uranium before these stages comprises 99.3% U-238 and only 0.7% U-235. It can be processed either by diffusion methods, to increase the proportion of U-235 sufficiently to make the fuel useful in power reactors, or processed directly in a reactor where the burning of the U-235 can release enough neutrons to convert some or most (with cycling) of the U-238 into Pu-239 which can then itself be burned. Of course instead of burning the fuels they could be diverted for weapons production.

3. FUEL ENRICHMENT

The building of an enrichment plant, to concentrate U-235 has been until recently a particularly massive technological investment. The difficulty arises in separating two chemically identical isotopes, whose distinction lies only in their slightly different masses. The classical method, which was used during the war on the Manhattan project, and which is still the basis of the nuclear development of the major powers, is the method of diffusive separation. The uranium is passed, in the form of its gaseous compound UF_6, uranium hexafluoride, through a porous medium at high pressure. The medium is a partition in a chamber some 30 ft. long, which must be able to withstand high pressures without any leak whatsoever. The differential rate of flow of the two types $U^{235}F_6$ and $U^{238}F_6$ through the medium effects the separation. The maximum enrichment ratio per chamber is given by

$$y_1/y_2 = k\ (x_1/x_2) \quad ; \quad k = \sqrt{M_1/M_2} \qquad (3),$$

where the gas flowing out of the chamber is considered split into two streams, such that the ratio of $U^{235}:U^{238}$ in one stream is y_1/y_2 and in the other stream is x_1/x_2.

The value of k, the enrichment factor per stage, is given by the square root of the ratio of the masses of the two component forms of UF_6. Its value is 1.00118, and in a practical case would fall even closer to unity. Estimates of the number of diffusion chambers needed to go from a U235 fraction of 0.7% to one of 94% give numbers between two and four thousand. The power needed to run such a chain is of the order of hundreds of megawatts; it is estimated that the Oak Ridge plant which first produced enriched uranium for atomic weapons consumed 250 megawatts. The nature of the porous medium which performs the separation is classified, but the French and almost certainly the Chinese have been able to develop the medium for use in their plants. However, the building and operation of a diffusion enrichment capability is clearly a major industrial undertaking, which could scarcely be concealed for long, and would not be undertaken lightly by a country with limited power resources.

The alternative form of enrichment plant using a high-speed centrifuge to separate the isotopes is distinguished by its potential economy of cost rather than of scale. Each separation stage comprises a high speed centrifuge which separates particles on the basis of mass, in a precisely equivalent way to the centrifuge commonly encountered in the laboratory. The number of separation stages needed is measured in hundreds but the power requirements are much less severe. Because the development of the gas centrifuge separator is one of the greatest technical threats to non-proliferation it is sufficiently important to warrant a separate treatment.

4. REACTORS FOR FUEL PRODUCTION

A chemically much simpler route than that of enrichment is to use a reactor to provide fissile Pu-239 from U-238, and then to separate the plutonium chemically. The following brief outline of reactors should be of particular interest to non-specialists. The aim of a reactor is the controlled fission of U-233, U-235 or Pu-239 to give energy, neutrons, and smaller nuclei, the fission fragments. For power generation it is the most economical production of energy which is needed, and 1lb. of nuclear fuel (e,g. U-235) provides the equivalent of complete combustion of 1500 tons of coal or 300,000 gallons of 100 octane liquid fuel, In the reactor the neutrons emitted during fission are allowed to bombard neighbouring nuclei, to cause these to split and maintain the chain reaction. As long as one neutron per fission can be used to promote another fission the reaction is self-sustaining.

4.1 Fissile Nuclides

To produce U-233 or Pu-239 as well as power, it is only necessary to utilize one neutron for power, but spare neutrons must be available for the conversion of Th-232 or U-238, the more abundant, fertile isotopes. These conversions are represented by equations (1) and (2). The question arises of how many neutrons are in fact released per fission;

Nuclide	ν Number of Neutrons/fissions	η thermal Output n / Input thermal n	η^f Output n / Input fast n
U-235	2.51	2.28	2.4
U-235	2.47	2.07	2.3
Pu-239	2.90	2.10	2.7

Table 1. Neutrons made available from fission processes.

4.4 Critical Mass

The larger the mass of nuclear fuel in a reactor, the fewer the neutrons which can escape, per unit mass. The mass at which a reactor "goes critical", engendering a self-sustaining chain of fission, varies with the geometry, and the enrichment of the fuel. For instance a uranium salt with 90% U-235 would need only 1kg of U-235 to go critical, but if the U-235 is mixed in natural proportions with U-238, 200 kg is needed in a mass of 30 tons of uranium, assuming a graphite moderator. In an actual reactor more than the critical amount of fuel must be fed initially into the core, and control rods of poison are inserted to absorb the excess neutrons. As the fuel burns away the rods can be withdrawn, or are themselves made of burnable material which is consumed during the neutron capture at an appropriate rate.

The mainstream of power reactors ar present used in the programs of the nuclear nations are CO_2- or water-cooled graphite - or heavy-water moderated burner reactors, in which up to 3% of the initial U-238 is eventually burned. As only 0.7% was originally present as fissile uranium, it is clear that a good measure of conversion of U-238 to Pu-239 can be achieved, and indeed such reactors are the main present-day source of weapons-grade plutonium. A burner reactor can in fact use either enriched fuel, which is nevertheless not sufficiently enriched for use as effective nuclear explosive; it can then be water moderated, or it can use non-enriched fuel, which is partially converted to separable weapons-grade Pu-239, but needs heavy water or very pure graphite on a large scale for moderation. By charging a 12% rent on heavy water stocks, and only 4% on enriched uranium, the AEC of the U.S. has tried to prevent the spread of Pu-239 production in burner reactors.

4.5 Breeders

It is not the burner, but in the long run the breeder reactor which is potentially the most productive source of Pu-239 or U-233 for weapons. The neutrons emitted from a fission process are fast. If a reactor has no moderator, it is termed a fast reactor, and fuel for such a reactor must contain at least 25% of a fissionable nuclide, because the susceptibility of the other nuclei (specifically U-235) to fission by fast neutrons is lower than for thermal neutrons, so one can afford to let fewer escape. The rest of the material in the reactor core must be of high nuclear mass, to prevent moderation by elastic scattering, and must not present a large cross-section for neutron absorption reactions other than fission. This rules out water for cooling, a d sodium or potassium or a mixture is used as a coolant, for their good moderating and thermal conducting properties. Gas coolants are also being produced. The reflector surrounding the core could be of iron or of uranium, both with high mass numbers.

4.51 Fast Breeders

The technical problems in designing a fast breeder reactor have been numerous and daunting. The fuel has to be held compact for good neutron economy but the ability to extract the heat produced calls for a dilute fuel, for the most economical working, which would not apply so powerfully to a non-clandestine weapons programme. Fuel elements must be found which do not require reprocessing, that is having the plutonium separated from the fission products, until at least 20% of the fuel has been used. Metal elements which suffer radiation damage and would disintegrate may not be used except possibly in experimental reactors, so uranium oxide is substituted, but this reduces the number of neutrons available per fission per unit mass. Finally control of the reaction is more difficult than with thermal reactors. This control, which aims at a very high fission rate, is achieved using the small fraction of "delayed" neutrons from subsidiary reactions. For U-233 fission the fraction of delayed neutrons is 0.26, for U-235 0.65, and for Pu-239 0.21%. These are delayed by from 0.17 seconds to 55 seconds after the fission, and allow the introduction of just enough "friction" in the system to prevent runaway.

A diagram of a breeder reactor, although it could depict graphically the description outlined above, can give little idea of the complexities of design, many of which are in any case subject to security restrictions. The size of the core, containing the fuel elements, is about that of a dustbin. The coolant, liquid sodium, flows round the core and through the blanket of fertile material to transport heat to a steam generator for electrical power. The power density at the centre of a fast breeder is 0.8kw/cm^3, compared with 0.02 in a high-pressure naval boiler, 0.04 in a turbojet combustion chamber, and 2 in the chamber of an Atlas ICBM. The power density alone leads the engineering of a fast breeder reactor to be a major technical feat.

4.52 Thermal Breeders

The alternative approach to breeding is a thermal one. Pu-239 is not susceptible to thermal breeding, because its neutron output to input ratio $\eta^{thermal}$ is only 2.07 at thermal energies, which does not leave a margin for losses. The reaction can be made self-sustaining at epithermal energies, and this compromise also gives a lower power concentration, but has greater bulk and capital cost. The U-233 fission with its value of 2.28 for $\eta^{thermal}$ enables thermal breeding to occur; indeed U-233 can be used in breeders of all energies. The value 2.28 is really rather low, so it is necessary to use the best moderator D_2O, heavy water, and a heat removal system which minimizes neutron losses. These requirements have led to the development of the aqueous homogeneous thorium breeder, in which uranyl sulphate (the U-233 variety) in a dilute sulphuric acid solution, made up with D_2O, is pumped through a central "pot" where a critical volume is maintained. The circulating fluid is then pumped away through wider tubes to suppress the reaction.

4.6 Some Reactor Design Considerations.

Metallurgical and materials developments take up much of the effort of nuclear technology. Fuel elements for both burners and fast breeders most conveniently comprise rods of uranium compound. For those reactors which cannot utilize water cooling because of the high neutron capture cross-section of its protons, either gas cooling, or liquid sodium cooling is used. Carbon dioxide and helium gases are not corrosive, nor do they absorb neutrons, but they are not so efficient at heat transfer as water would be but they are not subject to pressure limitation. This implies working at higher temperatures where fuel elements of uranium oxide crack; nevertheless practical systems of this type have been developed for advanced gas reactors. No metal supports are available which can either resist cracking, or do not absorb neutrons. This has led to graphite supports and structures for gas-cooled reactors, which are, however, bulky, and involve high capital costs. Sodium cooling is more thermally efficient then gas cooling. In fact its potential for transporting heat from a reactor core has not been fully utilized. Uranium metal rods cannot go to extreme temperatures without swelling, and any attempt to restrict this with a metal sheath causes loss of neutrons. Uranium oxide does not swell, but does not deliver enough heat per unit mass to utilize the sodium cooling efficiently. Nevertheless, in practise uranium oxide is much used in sodium cooled fast reactors. Uranium carbide fuel elements combine the low expansion of the oxide with the thermal properties of the metal, and are under active development.

FIRST PUGWASH SYMPOSIUM

"Control of Peaceful Uses of Atomic Energy
with particular reference to Non-proliferation"

LONDON, 11 - 16th April, 1968

C.F. Barnaby (U.K.) I - 1

DEVELOPMENT AND CONTROL OF THE USES OF ATOMIC ENERGY WITH PARTICULAR REFERENCE TO NON-PROLIFERATION

BACKGROUND PAPER

1. INTRODUCTION

It is particularly appropriate to hold a symposium on the control of the peaceful uses of atomic energy in the year 1968 for several reasons.

(a) It is twenty-five years since Enrico Fermi's atomic pile went critical and the atomic age began. It is an appropriate time, therefore, to consider the impact that atomic energy has had upon international politics, warfare and man's welfare.

(b) The International Atomic Energy Agency has been functioning for a decade. The Agency was created to promote the peaceful uses of atomic energy and one of its main objects is to ensure that nuclear materials intended for peaceful uses shall not be diverted for military ends. Now is a useful time to examine the progress that the Agency has made during the first decade and what progress can be anticipated in the second decade.

(c) The first nuclear explosion for civil applications was recently set off in New Mexico, U. S. A. and it is important to consider the consequences of this.

(d) The recent past has seen the development of several new weapons systems including: A. B. M. systems; fractional orbital bombardment systems; and certain multiple-independently-targeted-re-entry vehicles, such as the American space vehicle. This time is, therefore, a crucial one for arms control discussions since future decisions on the deployment of these weapons will have important consequences for the arms race.

(e) During the next few years a very large increase in the number of nuclear power reactors used for electricity generation will take place. This, in turn, will result in the widespread production of plutonium. A critical examination of ways of safeguarding this plutonium to prevent the proliferation of nuclear weapons is, therefore, an urgent requirement.

(f) Recent work on the development of uranium seperation facilities and the effect of this on nuclear proliferation also needs urgent discussion.

It is hoped that the proposed symposium will provide a useful forum for the discussion of the relevant problems facing mankind at the end of the first quarter century of the atomic age and of some of the problems likely to occur during the next quarter century. The purpose of this paper is to provide some of the background material for these discussions.

2. DEVELOPMENT OF NUCLEAR ENERGY PROGRAMMES

Twelve years ago nuclear energy as a source of power was represented by one small reactor generating five megawatts of electricity (MWe) at Obninsk in the U. S. S. R. Since then there has been a rapid growth and spread of nuclear power for the production of electricity. This is shown in Table 1 which indicates the total power outputs of the nuclear reactors in operation at the end of 1966 in various countries.

Country	Total nuclear power output (MWe)
Belgium	10.5
Canada	226
France	1146
German F. R.	285
Italy	536
Japan	170
Sweden	9
U. K.	3456
U. S. A.	1957
U. S. S. R.	1532

Table 1. Nuclear power reactor outputs at end of 1966[1]

Between 1967 and 1970 inclusive Czechoslovakia, India, the Netherlands, Pakistan, Spain, and Switzerland will also put nuclear power reactors into operation (Table 2).

Table 2. Additional countries operating reactors 1967 - 1970 inclusive

Country	Power Output (MWe)
Czechoslovakia	150
India	580
Netherlands	47
Pakistan	125
Spain	593
Switzerland	350

The cumulative total outputs of reactors now operating, or expected to come into operation, are shown in Table 3 for the period up to the end of 1972. These totals are plotted on a log-log scale in Figure 1 and if the resultant straight line is extrapolated it can be seen that more than 200, 000 MWe will be generated by 1980; there is no evident reason why this total should not be reached. A summary of the power reactor programme in tabular form is given in Table 4.

Thus, in just over one decade 5 megawatts have grown to 10, 000 megawatts and in just over another decade this will grow to 200, 000.

Peaceful nuclear plants now operating produce more than 4000 Kgs. of plutonium per year. In the early 1970's this will increase to over 10, 000 Kgs. and to over 100, 000 Kgs. by 1980.

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(1) China has two reactors but they are relatively small; a 7 MWe reactor has been in operation for about ten years. China has concentrated on enriching uranium, rather than plutonium production, for its nuclear weapons programme.

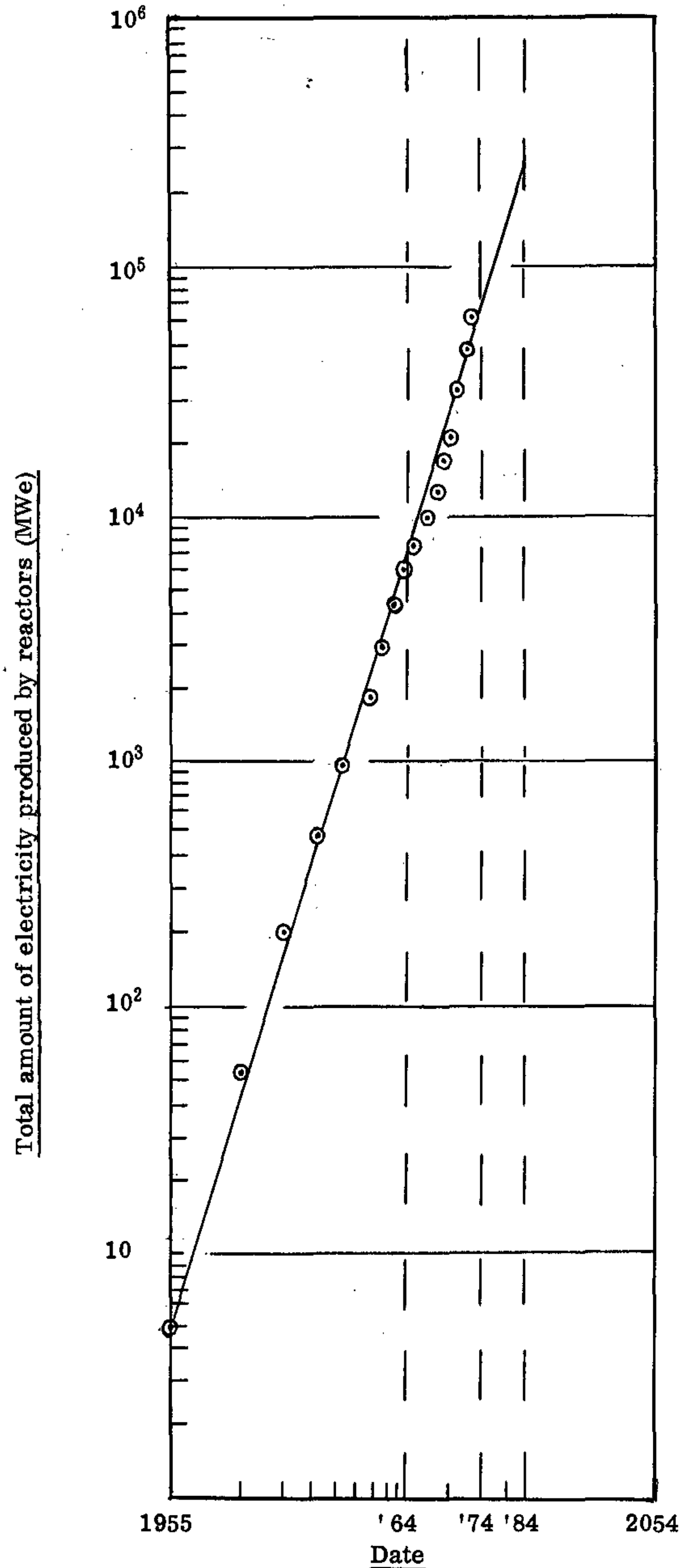

Fig. 1. Total amount of electricity produced by reactors since 1955.

Table 3. Cumulative totals of nuclear power reactor outputs up to 1972

1953	0	1964	6018	
1954	5	1965	7395	
1955	5	1966	9328	
1956	54	1967	11881	, predicted
1957	197	1968	16289	
1958	488	1969	20313	
1959	992	1970	31292	
1960	1302	1971	47424	
1961	1710	1972	64066	
1962	2800			
1963	4372	1980	> 200,000	

Table 4. Power reactor summary

	1967	Additional expected 1968-1972 incl.
Output over 100 MWe		
Number of stations	29	86
Number of reactors	41	94
Total capacity (MWe)	9980	52044
Countries	8	10
Output between 20 and 100 MWe		
Number of stations	19	3
Number of reactors	24	3
Total capacity (MWe)	1403	93
Countries	6	3
Experimental reactor outputs below 20 MWe		
Number of reactors	18	4
Total capacity (MWe)	164	48
Countries	9	1
Cumulative totals	11600	64000

At present, large industrial power reactors are in operation or under construction in 16 countries. In addition, there are a large number of research reactors scattered throughout the world. These are, in general, relatively small in output. Countries which have large research reactors but no power reactors include Australia, Austria, Brazil, Denmark, E. Germany, Indonesia, Israel,* Norway, South Africa and Yugoslavia. The research reactors of Israel, Norway and Yugoslavia produce enough plutonium to produce nuclear weapons at the rate of about 1, 1, and $\frac{1}{4}$ per year respectively. (It is usually assumed that about 5 Kgs. of plutonium are required to make a nuclear explosion). Most of the other research reactors have little military significance.

Nine countries can at present produce large nuclear reactors. These are U.S.†, U.S.S.R., U.K., France, China, W. Germany, Canada, Japan and Sweden. Five more, namely, Italy, India, Czechoslovakia, the Netherlands and Belgium, will probably also be able to produce large reactors in the forseeable future. The other 100 or so countries must import any reactors they require.

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* The research reactor of Norway (natural uranium, about 5 MWe rating) is a joint undertaking with the European Nuclear Energy Agency.

Reactors have been exported by Canada, France, U.K., U.S.A. and U.S.S.R. The countries to which reactors have been exported are shown in Table 5. Sweden also now competes for reactor contracts.

Table 5. Exported reactors

Country	Reactor	Rating (MWe)	In operation	Exporter
Australia	HIFAR	2.5	1958	U.K.
Denmark	DR-2	1.5	1958	U.K.
Italy	Latina	200	1962	U.K.
Japan	Tokai-Mura	158	1965	U.K.
W. Germany	FRJ. 1	1.5	1962	U.K.
	FRJ. 2	2.5	1962	U.K.
Austria	ASTRA	3	1960	U.S.A.
Belgium	SENA	266	1965	U.S.A.
	BR-3	10.5	1962	U.S.A.
Brazil	IEAR-1	1.5	1957	U.S.A.
India	Tarapur	380	1968	U.S.A.
Italy	SENN	150	1963	U.S.A.
	SELNI	186	1964	U.S.A.
Japan	JRR-2	2.5	1960	U.S.A.
	JPDR	11	1963	U.S.A.
	Tsuruga	300	1968	U.S.A.
Netherlands	SEP-BWR	50	1967	U.S.A.
Pakistan	PARR	1.5	1965	U.S.A.
S. Africa	Safari-1	5	1965	U.S.A.
Sweden	R-2	7.5	1960	U.S.A.
W. Germany	KRB	237	1966	U.S.A.
	KWL	250	1968	U.S.A.
	FRG	1.5	1958	U.S.A.
	VAK	15	1961	U.S.A.
Czechoslovakia	HWGCR	150	1968	U.S.S.R.
Yugoslavia	R-A	2.5	1959	U.S.S.R.
India	CIR	10	1960	Canada
	Rajasthan	200	1969	Canada
Israel	Dimona	6	1964	France
Italy	ESSOR	9	1967	France

Reactors are not the only problem in relation to the proliferation of nuclear weapons. Reactor fuel supplies are clearly important. In addition, nuclear weapons can be produced by any State which can extract and purify uranium-235. To do this, gaseous diffusion plants or gas centrifuges are necessary. Electromagnetic separation, liquid thermal diffusion, and chromatographic methods are probably not practicable, although the French have recently reconsidered the electromagnetic separation method.

Fuel Supplies

The major uranium exporting countries are the U.S., Canada, South Africa and Sweden; there are the other lesser producers. The uranium reserves of non-communist countries, which can be extracted for less than 10 dollars per lb. of uranium oxide, are given in Table 6.

Table 6. Cheap Uranium Reserves - Euratom Estimates

Country	Metal (tons)	Ore Content (%)
Canada	145,000	0.1
U.S.A.	134,000	0.2
S. Africa	115,000	0.017
France	26,000	0.14
Australia	10,000	0.09-0.15
Congo	8,000	0.3
Portugal	5,500	0.12
Gabon	5,000	0.45
Argentina	3,800	0.1-0.2
Italy	1,500	0.10
Spain	1,500	0.11
India	1,200	0.06
Japan	1,000	0.042
W. Germany	800	0.2-0.5

Gas Diffusion Plants for Purifying Uranium-235

There are three of these plants in America, which have produced the majority of the fissile material for the American nuclear weapons programme. There are two plants in the U. S. S. R., one in the U. K., one in France, and one in China. No plants have so far been built in the non-nuclear countries. They are extremely costly to build and operate and consume enormous quantities of electric power. The cost of building a gas diffusion plant is probably about a billion dollars and the running cost is probably about 100 million dollars per year.

Gas Centrifuges

Development work on these has been done in the U. S., W. Germany, the Netherlands and Japan. The capital cost of a centrifuge plant would probably be of the same order as that of a diffusion plant but the power consumption would be less and it would be easier to conceal. It must be concluded that they will be eventually developed and used (probably by W. Germany and Japan).

Plutonium Separation Plants

India has built a plutonium plant at Trombay, aided by the United Kingdom; the cost of building a small plant is probably about 50 million dollars. Canada has not bothered to build a separation plant. There is strong internal pressure to build a plant in Japan but this has not so far been done. There is a chemical separation plant in Belgium, owned by ten members of the European Nuclear Energy Agency. No other non-nuclear country has such a plant.

3. NUCLEAR CAPABILITIES

The nuclear capabilities of the industrial non-nuclear powers are summarized in Table 7.

In general the U. S. and U. S. S. R. have tended to use enriched uranium fuel and hydrogen moderator in their reactor technology whereas France and the U. K. have concentrated on natural uranium fuel and enriched or low cross-section moderator. Canada, India, Sweden (and Israel) also prefer natural uranium fuel.

Table 7. Nuclear Capabilities of Non-nuclear Weapon Countries

Country	Uranium Supplies	Reactors	Separation Plants	Remarks
Canada	Has world's largest assured uranium resources in most economical price range. Canada has about one-third of known uranium at an extraction cost of about $7 per lb. plus huge additional reserves.	Only non-nuclear country to export large reactors. All Canada's reactors are home-built and designed, and are all based on natural uranium. Canadian reactors now produce 230 MWe; by 1970 there will be an additional 1010 MWe produced.	None	In 1946 the Canadian Government decided not to develop nuclear weapons. Her own reactors are designed to burn-up as long as possible; therefore the plutonium produced is much less valuable for weapons.
W. Germany	Domestic supplies are small but adequate for a small nuclear programme. Has to import enriched uranium.	Germany has built reactors, mostly to use enriched uranium. By 1970 she will have eight large reactors - three from the U.S. Five of these will use enriched uranium. Much larger reactors will be built after 1970. Present output - 285 MWe. By 1970 there will be an additional 675 MWe.	Work has been done on gas diffusion and centrifuges. No separation plant for plutonium.	Home production of plutonium from the three large reactors which will be home built and will use natural uranium will, by 1970, produce at least 160 Kg of plutonium per year.
Japan	Japan has a small domestic supply of natural uranium which can be extracted at low cost.	Japan has not yet got far in self-sufficient reactor programme. Reactors are mostly imported from U.S. and use enriched uranium. A U.K. built power reactor (Tokai Mura) uses natural uranium from Canada. A major programme to build six new power reactors by 1976 has been started - three of these will be large. All six will need enriched uranium; hence the centrifuge development. Present output - 170 MWe. By 1970 there will be an additional 1030 MWe.	Much research work has been done on centrifuges by Japan who will probably develop them. There is strong internal pressure to build a plutonium separation plant.	U.K. may separate plutonium from Tokai-Mura reactor and return it under contract. Japanese industry could produce reactors. If she develops gas centrifuges to a low percentage of enrichment the only bottleneck to self-sufficiency would probably be uranium supplies.

Cont...

Table 7. Cont...

Country	Uranium Supplies	Reactors	Separation Plants	Remarks
India	India has substantial quantities of low-to-medium priced uranium, equal to about one-third of France's resources (these are inadequate for France's nuclear programme).	Two major power reactors are being constructed. The Tarapur reactor (U.S. built) uses slightly enriched uranium which will have to be imported. The Rajasthan reactor (Canadian built) uses natural uranium. There are plans for three other reactors using natural uranium. Output by 1970 - 580 MWe.	Has a plutonium separation plant - built with U.K. and U.S. aid.	Of non-nuclear powers India has made most effort towards self-sufficient fissile material production (plutonium). With completion of Tarapur and Rajasthan reactors Indians believe that they will be able to construct their own reactors from their own resources and be independent.
Sweden	Has about one-half of world's reserves in medium price range but no supply of cheap uranium. Potential is only exceeded by the U.S. and Canada.	Sweden now competes for reactor contracts. The R-4 Eva reactor, in operation by 1968, uses enriched uranium from U.S. but has been designed for natural uranium as well. Therefore it could be run for plutonium production. Present output from Swedish reactors is 9 MWe, by 1970 there will be an additional 540 MWe.	No separation plant.	Has embarked on self-sufficient reactor development. Sweden is an important potential reactor exporter and exporter of fuel elements.
Italy	Very small quantities.	Has one power reactor (natural uranium) built by U.K. at Latina and two (enriched uranium) by U.S. One large research reactor is being built by Euratom. Present output of Italian power reactors is 540 MWe.	No separation plant. Small plants for processing fuel elements are being built.	U.K. government has agreed to separate plutonium produced by Latina reactor and to return it to Italy. Shipments are likely to be at rate of about 120 Kg/year.

Cont....

Table 7. Cont...

Country	Uranium Supplies	Reactors	Separation Plants	Remarks
Switzerland	None known.	Three large reactors are planned with U.S. contractors and using enriched uranium. Switzerland also has two large research reactors. Total output by 1970 - 360 MWe.	No separation plant.	All reactors will be operated under IAEA safeguards.
Belgium	Some natural uranium was accumulated by Belgium before the Congo gained independence in 1960.	Belgium has a U.S. built power reactor. Present output - 10 MWe.	Has a separation plant but this is owned by 10 members of the European Nuclear Energy Agency.	ENEA has agreed that the plutonium should not be used for military purposes; the Agency has its own safeguards system.
Netherlands	None	The Netherlands has a U.S. built reactor using slightly enriched uranium. Output in 1968 - 47 MWe.	No separation plant.	Reactor will be under IAEA safeguards.
Czechoslovakia	Some domestic uranium production.	U.S.S.R. - built natural uranium reactor goes into operation in 1968. Output - 150 MWe.	No separation plant.	
Israel	Small supplies of natural uranium are available as a by-product of the phosphate industry.	The French are co-operating in the Dimona reactor programme. The fuel used is natural uranium. Output - 6 MWe.	No separation plant.	The French have placed no restriction on use of the reactor. Israel is also interested in large reactors for desalination of sea water.
United Arab Republic	None	Egypt has a plan for a 150 MWe reactor at Alexandria.	No separation plant.	

A reactor built for enriched uranium cannot normally be used with natural uranium. Therefore, a country which uses enriched uranium reactors must depend on a country with a gaseous diffusion plant for fuel supplies. In practice, this means the U.S. or the U.S.S.R. A country with a natural uranium reactor facility has a potential plutonium production, which can be fuelled from many different sources (there is, at present, an excess in world supplies of uranium ore). Reactors exported from the U.S. and U.S.S.R. are, therefore, easier to control than those exported by Canada, France and the U.K.

The amount of plutonium bred from uranium-238 per megawatt - year of electrical power ranges from about 0.2 Kg. in the case of enriched uranium reactors to about 0.5 Kg. in the case of natural uranium reactors. The minimum potential plutonium outputs in kilograms per annum in 1970 is shown in Table 8. Potential plutonium outputs will, of course, continue to increase rapidly after 1970.

Table 8. Minimum Plutonium Production in 1970

Country	Preferred Fuel	Plutonium Output (Kg)	Country	Preferred Fuel	Plutonium Output (Kg)
Belgium	Enriched U	2	Netherlands	Slightly enriched U	10
Canada	Natural U	650	Pakistan	Natural U	60
Czechoslovakia	Natural U	75	Spain	Enriched U	120
France	Natural U	1200	Sweden	Natural U	120
W. Germany	Enriched U with some natural U	235	Switzerland	Enriched U	70
India	Natural U	190	U.K.	Natural U	1250
Israel	Natural U	5	U.S.A.	Enriched U	1200
Italy	Natural U & enriched U	160	U.S.S.R.	Enriched U	600
Japan	Natural U	300			

The thirty countries which produce, will produce, or are considering producing, significant amounts of plutonium on their territory are shown below: -

Powers with deliverable nuclear weapons	Near-nuclear powers	Other powers who are producing, or who will soon produce plutonium	Powers who intend to build reactors and therefore to accumulate plutonium	Countries considering a power reactor programme
China	Canada	Belgium	Argentina	Australia
France	Czechoslovakia	E. Germany	Austria	Denmark
U.K.	W. Germany	Israel	Finland	Portugal
U.S.A.	India	Netherlands	Greece	S. Africa
U.S.S.R.	Italy	Norway	Roumania	
	Japan	Pakistan		
	Sweden	Spain		
		Switzerland		
		Yugoslavia		
5	7	9	5	4

From the above information it is clear that a distinction must be made between countries which have a self-sufficient nuclear capacity and those who must rely on importing fuel or reactors from others or who must persuade others to separate their plutonium. The validity of the distinction will depend on the effectiveness of international safeguards and the availability of natural uranium on the world market.

4. SAFEGUARDS

Very few nuclear facilities have been constructed in other countries, by the nuclear powers, without safeguards. The main exception is France who has been prepared to export reactors without any guarantee, although there is some evidence that this policy is changing. The Indian C.I.R. reactor was built by Canada without safeguards but the Rajasthan reactor is now being built by Canada with the provision for mutual inspection with a Canadian reactor in Ontario. The United States exports reactors to members of the E.E.C. on the basis that Euratom is itself a suitable inspecting agency. The U.S.S.R. does not maintain formal safeguards; the reactors exported from the Soviet Union are mainly small and it is argued that there is no need for special arrangements to ensure that the fissile material produced by them is not put to military use.

Up to now safeguards usually took the form of bilateral agreements of inspection and guarantees between the country providing the nuclear facility (i.e. Canada, U.K. or U.S.) and the receiving country. There is a growing tendency for exporting countries to rely on the I.A.E.A. to provide safeguards. The U.S., for example, has transferred to the Agency safeguards responsibilities assumed under bilateral agreements between the U.S. and thirteen countries.

The chronological development of the I.A.E.A. safeguards is shown below:-

1957 - I.A.E.A. comes legally into existence.
1958 - First I.A.E.A. agreement to supply nuclear material to Japan, with safeguards where appropriate.
1961 - First set of safeguards procedures for reactors of up to 100 MW (thermal), (i.e. about 30 MWe), approved.
1962 - First safeguards inspection in Norway and Finland.
1963 - Safeguards procedures extended to include all reactors.
1965 - Revised safeguards system adopted.
1966 - Revised safeguards system extended to include reprocessing plants.

Present I.A.E.A. agreements cover 65 reactors in 29 countries, (Table 9) with total thermal capacity of 3200 $MW_{thermal}$ (about 900 MWe); this represents less than 8% of the capacity of existing civil reactors. Of these countries well over one-half are developing countries; European countries have not, in general, supported the I.A.E.A. safeguards system.

Table 9. Countries with I.A.E.A. Safeguards Agreements

Argentina	China (Taiwan)	Indonesia	Norway
Austria	Congo	Iran	Pakistan
Australia	Finland	Israel	Phillipines
Brazil	Ghana	Japan	Portugal
Chile	Greece	Korea, Republic of Mexico	South Africa
Spain	Uruguay		
Switzerland	Vietnam		
Thailand	Yugoslavia		
U.K.			
U.S.A.			

The Statute of the I.A.E.A. authorises the Agency to apply safeguards: when it grants assistance to a State at the latter's request; when the parties to a bilateral or multilateral agreement on cooperation in nuclear matters request the Agency to apply safeguards to installations and materials covered by this agreement; and when a State requests the Agency to apply safeguards to any or all of its activities in the field of nuclear energy. The Statute requires the Agency to "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" (Article II). The Agency is also required to "conduct its activities in accordance with the purposes and principles of the United Nations, to promote peace and international good will -----" (Article III B. 1.).

The Statute lays down the way in which verification shall be carried out as follows:-

The Agency is given the right:

(a) to examine the design of facilities and to approve them only if the Agency is sure they will not serve any military purpose and will permit the effective application of safeguards;

(b) to require the maintenance and production of operating records to ensure the accounting for special fissionable materials;

(c) to ask for reports periodically on the operation of the reactor designed to ensure that the Agency will know what nuclear fuel has been received and what plutonium has been produced;

(d) to approve the means of reprocessing irradiated fuel;

(e) to send into the territory of States inspectors designated by the Agency after consultation with the State concerned;

(f) these inspectors have rights of access to persons, places and data which are relevant to the use of nuclear materials, equipment or facilities;

(g) to require the observance of any health and safety measures prescribed by the Agency.

Unless a State submits all its nuclear activities to safeguards, the application of the system remains limited to specific nuclear installations and materials.

The I.A.E.A. safeguards system must operate in such a way that the applications of safeguards must not hamper the economic or technological development of a State. Commercial and industrial secrets which the Agency staff may meet while implementing safeguards must be protected.

The Statute details sanctions which can be applied in the event that a State does not comply with its safeguards obligation. The non-compliance will be reported to the Agency's Board of Governors; the Board will call on the State to remedy the non-compliance; if the State persists in its non-compliance the Board may curtail or suspend the Agency's assistance and call for the return of material and equipment made available and/or suspend the membership rights and privileges of the State; the Board of Governors must report to the Security Council and all members of the United Nations and the Agency.

The Statute itself is, however, not enough to operate the safeguards system. The Board of Governors has, therefore, drawn up the necessary operating procedures.

When the Agency was asked for the first time, by Japan, in 1958 to supply assistance, in the form of the provision of a quantity of nuclear fuel to which safeguards would have to be applied, a set of interim procedures was used.

In 1961 the Board adopted a system for reactors of up to 100 MW thermal power. This was, in effect, confined to research reactors. In 1963, the system was extended to power reactors, which are, of course, the real producers of plutonium. The Board also decided to review the 1961 safeguards document. As a result, a new document was produced, and accepted in 1965, which constitutes the basis of the present safeguards operation. The 1965 document is in much clearer language than the earlier one and is, in fact, easily understood. The new system applies primarily to special fissionable material which means: plutonium-239; uranium-233; uranium enriched in the isotope 235 and 233; any material containing one or more of the foregoing; and such other fissionable material as the Board of Governors shall from time to time determine. Not included is natural uranium, uranium depleted in the isotope-235, or thorium. In 1966 the Agency's safeguards were further extended to cover facilities for the reprocessing of reactor fuel, after use.

An important point in the safeguards document is the provision for review from time to time in the light of technological developments and experience.

Frequency of Inspections

The maximum frequency of routine inspections of a reactor, and of the safeguarded nuclear material in it, shall be determined from whichever is the largest of the following quantities:

(a) facility inventory;
(b) annual throughput;
(c) maximum potential annual production of special fissionable material.

In the case of small quantities (e.g. up to 1Kg. of plutonium) no inspection takes place. In the case of, say 55-60Kg. of plutonium, twelve inspections may take place annually. If even larger quantities are involved inspectors have the right of access to the installations at all times.

The frequency of inspections for reprocessing plants and the safeguarded nuclear material in them depends on the annual throughput. If the throughput is less than 5Kg. of plutonium it may be inspected twice a year. If the throughput exceeds 5Kg. the plant may be inspected at all times. If it exceeds 60Kg. continuous inspection is envisaged.

Exemption limits are prescribed for nuclear materials held in small quantities or produced at low levels. The following quantities of exempt materials may be held by a State:-

(a) A total of one kilogram of special fissionable material;
(b) Ten tons of natural uranium and/or depleted uranium with an enrichment of more than 0.5 per cent;
(c) Twenty tons of depleted uranium with an enrichment of less than 0.5 per cent;
(d) Twenty tons of thorium;
(e) Nuclear material produced in a reactor whose annual rate of production is less than 100 grammes of plutonium or whose thermal power is less than 3 MW.

Inspections

Inspection activities are required to be the minimum consistent with the effective application of safeguards. During an inspection the inspector may audit the records and accounts; verify the nuclear material under safeguards, either by physical inspection measurements or sampling; examine any facility under safeguards, including checks of measuring instruments and operating characteristics; and check operations generally. Inspectors may not operate any facility or direct the staff in any facility. One week's notice of any inspection must be given. Before an inspector is sent for duty in any State, the Government of that State has to be consulted. If it accepts the designation, the Government shall cooperate as much as possible in allowing the inspector to function on its territory.

The inspection apparatus consists of : (1) the Inspector General (Australia); (2) the Director of the Division of the Safeguards and Inspection (Yugoslavia); (3) the ten officers of the Agency whom the Director General has been authorised by the Board of Governors to use as inspectors. Two of these inspectors come from the U. S. A., two from the U. S. S. R., one from each of Argentina, France, Hungary, India, Japan and the U. K. In addition, 16 other Agency staff members are available to assist in inspections when particualarly specialised knowledge is required.

The fundamental basis of the Agency's safeguards system depends upon an agreement between the Agency and the State concerned. The Agency's main business in the field of safeguards has so far arisen from requests by the parties to bilateral agreements to apply safeguards to the arrangement and from the unilateral requests by the U. K. and the U. S. A. to apply safeguards to a number of reactors.

EURATOM

Each of Euratom's agreements with third countries stipulates that materials supplied to Euratom should be used for non-military purposes. All enterprises have to report on their equipment and have to make regular declarations to the Commission of stocks, transfers and transactions of nuclear material.

Euratom inspectors visit installations and undertake physical and accountancy checks on materials held. Enterprises which fail to carry out their obligations are liable to various types of penalty including, in the last resort, the denial of access to fissionable material. Euratom's control system is the first to have legal force over a number of nations. The inspection system is similar to that of the I. A. E. A. except that Euratom maintains a relatively higher number of inspectors.

Euratom has bilateral agreements with the U. S. A. for a joint nuclear power station programme and a joint research and development programme. The U. S. Atomic Energy Commission and the Euratom Commission have agreed to exchange information on fast-breeder reactor research on which both sides are engaged. A bilateral agreement with the U. K. covers the exchange of information in research and also exchanges or personnel. The U. K. is supplying fissile materials for the Community's research reactors. Euratom - Canada agreements cover joint research on natural uranium heavy-water moderated reactors. Agreements with Brazil and Argentina provide for cooperation over a wide field of activities including the exchange of research information and improvement of prospective techniques for raw materials.

The European Nuclear Energy Agency

This Agency of the Organisation for Economic Cooperation and Development set up a control system before the I. A. E. A. came into operation. The object of this safeguards system is to ensure that "the operation of joint undertakings established by two or more Governments or by nationals of two or more countries on the iniative or with the assistance of the Agency, and materials, equipment and services made available by the Agency, or under its super vision, by virtuce of agreements concluded with the Government concerned shall not further any military purpose". The members of E. N. E. A. are Austria, Belgium, Denmark, France, W. Germany, Greece, Iceland, Italy, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and the United Kingdom. The controls are based essentially on the same concepts as those of the I. A. E. A. and Euratom safeguards systems. A point of interest is that an independent judicial tribunal, known as the European Nuclear Energy Tribunal, consisting of seven independent judges has been set up which is competent to consider appeals against decisions concerning the application of the safeguards regulaions and decisions prescribing the sanctions which the Agency may impose. The President of the Tribunal can grant a warrant for the execution of inspection measures which are resisted by an installation. Sanctions may include the suspension or termination of the delivery of materials, equipment or services supplied by the Agency or under its supervision. It may even be required that such materials and equipment are returned. The Tribunal may, however, also order the Agency to make reparations for any unreasonable damage caused by the Agency or by its staff in the performance of their duties, including inspections. The E. N. E. A. system has provided valuable experience and knowledge concerning the practical aspects of the application of a safeguards system.

5. NON-PROLIFERATION

The basic requirement for a non-proliferation agreement is stated in the so-called 'Irish Resolution', which was unanimously adopted in 1961 by the United Nations General Assembly. This called for an agreement by which "nuclear States would undertake to refrain from relinquishing' control of nuclear weapons and from transmitting the information necessary for their manufacture to States not possessing such weapons, and States not possessing such weapons would undertake not to manufacture or otherwise acquire control of such weapons".

Agreement was reached in 1961 on the composition of a Disarmament Committee to consist of eighteen members namely, Brazil, Bulgaria, Burma, Canada, Czechoslovakia, Ethiopia, France, India, Italy, Mexico, Nigeria, Poland, Roumania, Sweden, U. S. S. R., United Arab Republic, U. K. and U. S. A. The first session of the E. N. D. C. took place in 1962; France did not attend the session and has continued to remain absent from the Conference. The permanent co-chairmen of the Conference are the heads of the U. S. and U. S. S. R. delegations. E. N. D. C. has been concerned with negotiations for a non-proliferation treaty from its inception.

The U. S., in 1963, advocated a programme for non-proliferation: the nculear powers should indicate that they would accept the same international inspection over their peaceful nuclear activities as they recommend for non-nuclear States; all transfer nuclear materials for peaceful purposes should take place under international safeguards; there should be a comprehensive test-ban treaty; and there should be an agreement not to transfer nuclear weapons into the control of States not possessing them. The Soviet Union expressed no interest in the first two proposals but made vigorous attacks on the multilateral nuclear force as a means of the dissemination of nuclear weapons.

The U. S. and the U. S. S. R. submitted draft treaties in 1965 which were not too dissimilar except that the Soviet draft included the provision that "parties to the treaty possessing nuclear weapons undertake not to transfer such weapons in any form - directly or indirectly through third States or groups of States - to ownership or control of States or groups of States not possessing nuclear weapons, and not to accord to such States or groups of States the right to participate in the ownership, control or use of nuclear weapons". Also, there was no article undertaking "to cooperate on facilitating the application of International Atomic Energy Agency or equivalent international safeguards on all peaceful nuclear activities".

During 1966, the U. S. and the U. S. S. R. made some modifications in their positions. The Soviet addition was a clause prohibiting the use of nuclear weapons against non-nuclear States party to the treaty and having no atomic armaments on their territory. The U. S. submitted important amendments. Article I was rewritten to include prohibitions on manufacturing and testing of nuclear weapons and Article II reflected the same changes in the obligations of non-nuclear States.

At the 21st. session of the United Nations, the General Assembly passed a resolution, sponsored by 45 nations including the U. S. and the U. S. S. R., urgently appealing to all States to take all necessary steps to facilitate, and achieve at the earliest possible time, the conclusion of a non-proliferation treaty. The resolution was adopted by the First (political and security) Committee by 100 votes to one (Albania) with Cuba abstaining. France supported the resolution. During the debate Bulgaria said that unless the U. S. A. ended its "manouvres to enable the German Federal Republic to fulfill its nuclear ambitions" it would be difficult, or impossible, to conclude a non-proliferation treaty. The U. S. delegate replied that the members of N. A. T. O. were convinced that while non-nuclear members of the alliance were entitled to a voice in their collective nulcear defence, as they were in their con ventional defence, this need not and must not involve or lead to the proliferation of nulcear weapons. After the vote the Soviet representative described the resolution as "an important contribution to the non-proliferation of nuclear weapons". He called for new efforts to conclude a treaty "closing all the loopholes tightly and preparing a way for further measures in the field of nuclear disarmament."

A resolution was sponsored by 47 non-aligned countries, urging all States to take all necessary steps conducive to the earliest conclusion of a treaty on the non-proliferation of nucl ear weapons and requesting the E. N. D. C. to consider urgently the proposal that the nuclear powers should give an assurance that they will not use, or threaten to use, nuclear weapons against non-nuclear weapon States.

A further resolution called for a conference of non-nuclear weapon States to take place, not later than July 1968, to consider the following and related questions:-

(a) How can the security of the non-nuclear States be best assured?
(b) How may non-nuclear Powers cooperate amongst themselves in preventing the proliferation of nuclear weapons?
(c) How can nuclear devices be used exclusively for peaceful purposes?

The President of the General Assembly appointed the following eleven States as members of the Preparatory Committee for the Conference on non-nuclear weapon States: Chile, Dahomey, Kenya, Kuwait, Malaysia, Malta, Nigeria, Pakistan, Peru, Spain and Tanzania.

In 1967 the U. S. and the U. S. S. R. tabled a draft treaty in Geneva, to the E. N. D. C. The critical Clause III of the treaty, dealing with safeguards and inspection, was left blank. The agreed text retained the main lines of the Irish Resolution. The text is given in Appendix I.

The recent United Nations report on the Probable Effects of the Use of Nuclear Weapons assessed the possible proliferation of nuclear weapons. The report said that there were only about six countries in the World, other than the five nuclear powers, which could afford the cost of a "small high-quality nuclear capability", estimated at 560 million dollars per year. These countries were Canada, Czechoslovakia, West Germany, Italy, India and Sweden. Japan was not included because its present military expenditure was so small that it would involve a major switch of national resources to achieve a nuclear capability. The quoted cost can be arrived at, in orders of magnitude, as follows:

To product the first bomb, if it were based on plutonium -

Uranium refinement, reactor and separation plant	$120 million
Design of the bomb and its production	20
Test range and equipment	80
	$220 million

Annual costs for maintaining the production of bombs would be about 5 million dollars/bomb.

Cost of Delivery System. The cost of developing solid fuelled rockets and the necessary guidance system would be likely to be about 700 million dollars, including the development of a re-entry warhead.

A rocket test range and testing equipment would probably cost a further 200 million dollars and the rocket production programme a further 800 million dollars.

Weapon development to produce nuclear weapons for rocket warheads would cost about 500 million dollars.

If it were decided to eventually produce a thermonuclear weapon a start would probably be made with enriched uranium rather than plutonium. This would be somewhat more expensive because of the cost of a diffusion plant.

A minimum cost for a modest nuclear force using plutonium is therefore likely to be about 2.5 billion dollars or, using uranium, about 3.3 billion dollars.

The present defence budgets of the powers mentioned by the U.N. Committee are shown in Table 10. The cost of providing a nuclear capability would be averaged over a number of years. In the peak years, however, about 1 billion dollars would be added to the defence budget. Most of these countries are, however, enjoying a high rate of growth and consequently the impact of the necessary increase in the defence budget for a modest nuclear force will steadily decrease for such countries.

Table 10. Defence Budgets of near-nuclear powers

Country	Defence Budget (billion dollars)	% of Gross National Product
Canada	1.4	4
Czechoslovakia	0.7	4
W. Germany	4.9	5
India	2.1	5
Italy	2.0	3.5
Japan	0.9	1
Sweden	0.9	5

The route taken by the present nuclear powers to acquire nuclear weapons and delivery systems has varied. The first fission weapons of the U.S.A. and China used uranium-235 as the fissile material; those of the U.S.S.R., the U.K. and France used plutonium-239 as the fissile material. The fissile material used in the thermonuclear devices of the four Powers that have exploded them, China, U.K., U.S.A. and U.S.S.R., was uranium-235 in each case. Each of the present five nuclear powers has developed, or is developing, missile submarines and also, apart from the U.K., long-range missiles. The delivery systems of France, U.K., U.S.A. and U.S.S.R. also include supersonic bombers; China, (as far as is known) and the U.K. are relying on subsonic bombers.

The comparative strategic strengths of these powers, as estimated by the Institute of Strategic Studies, for early 1968, are shown in Table 11.

Table 11. Estimated Comparative Strategic Strengths of the Nuclear Powers

Category	China	France	U.K.	U.S.A.	U.S.S.R.
Missile and air power					
Land-based I.C.B.M.'s	-	-	-	1054	520
Fleet ballistic missiles	-	-	-	656	130
I.R.B.M.'s and M.R.B.M.'s	*	-	-	-	725
Long-range heavy bombers	-	-	-	520	150
Medium bombers	12	60	80	75	1100
Sea power					
Carriers (all types)	-	4	5	28	-
Cruisers	-	2	-	14	20
Ocean-going escorts	20	48	71	330	198
Ballistic missile submarines	1	-	2	37	45
Attack submarines	30	21	36	103	335

* China is expected to have I.R.B.M.'s in 1968 and some I.C.B.M.'s by the early 1970's.

I.C.B.M. - Intercontinental ballistic missile; I.R.B.M. - intermediate range ballistic missile; M.R.B.M. - medium range ballistic missile.

The details of the major nuclear delivery systems of the Superpowers are shown in Table 12. None of the other powers could expect to compete with these systems.

The capabilities of the near-nuclear powers to develop nuclear delivery systems are summarized in Table 13. It should be also noted that Israel has an advanced missile industry capable of producing a rocket weapon. The United Arab Republic has three bombardment missiles (ranges 250, 400 and 600 miles) and Russian bombers designed to carry nuclear weapons (Egypt is also developing a jet engine). Although her rockets would probably not carry a nuclear weapon Egypt has an effective delivery system in her possession.

6. FRACTIONAL ORBITAL BOMBARDMENT SYSTEMS

The U.S. Defence Secretary announced earlier this year that the U.S.S.R. was probably developing a system for putting powerful space bombs in orbit around the earth. This system involves launching a nuclear warhead into a very low orbit, about 100 miles above the earth (an I.C.B.M. may reach a peak altitude of 800 miles); at a given point, and before the completion of the first orbit, a retro-rocket would slow down the warhead, causing it to drop out of orbit onto the target. The potential warhead is estimated to be between one to three megatons.

The U.S. Defence Department has revealed that the U.S. is developing a multiple independently targeted re-entry vehicle with a guidance system and thruster

Table 12. Major Nuclear Delivery Systems (missiles) of the Superpowers

	Name	Range (miles)	Estimated Warhead
U.S.A.	LGM - 25C	10,000	5+ megaton
	LGM - 30A	6,500	1+ megaton
	LGM - 30F	9,000	2 megaton
	UGM - 27A	1,380	0.7 megaton
	UGM - 27B	1,700	0.7 megaton
	UGM - 27C	2,850	0.7 megaton
	MGM - 13B	1,380	Kiloton range
	MGM - 31A	400	Kiloton range
	MGM - 29A	75	Kiloton range
U.S.S.R.	ICBM - Scrag	Orbital	? 30 megaton
	ICBM - x	5,000 +	10 megaton
	ICBM - x	5,000	10 megaton
	ICBM - Sasis	5,000	5 megaton
	ICBM - x	10,000	20 megaton
	ICBM - Savage	6,000	1 megaton
	IRBM - Skean	2,100	1 megaton
	MRBM - Sandal	1,100	1 megaton
	SLBM - Sark	400	1 megaton
	SLBM - Serb	650	1 megaton
	SLCM - x	300	kiloton range
	SLCM - x	200	Kiloton range
	SRM - Scud	20	Kiloton range
	CRM - Shaddock	250	Kiloton range

x no name assigned.

LGM - silo-launched missile; UGM - underwater-launched missile;
MGM - mobile-guided missile; SLBM - submarine-launched ballistic missile;
SLCM - submarine-launched cruise missile; SRM - short-range missile;
CRM - cruise missile.

Table 13. Delivery System Development Capabilities of the Near-nuclear Powers

Country	Aircraft Industry	Electronics Industry	Missile Industry	Remarks
Canada	Substantial. Has developed aero engines. Canada has aircraft with nuclear strike capability over short-to-medium range.	Substantial.	Has developed solid rocket propulsions in high altitude sounding rockets.	Has basis for rapid development of a quality delivery system if government chose to do so. In practice, would probably co-operate with U.S.A.
Czechoslovakia	Small - for light aircraft.	Small.	None.	Poland has done some rocket development, so these two could co-operate.
Germany, W.	Smaller than would be expected from industrial strength.	Substantial.	Smaller than would be expected. Would take a long time to develop high quality missile delivery system to suit its needs.	Large number of different delivery systems acquired for American nuclear bombs and warheads under NATO dual-key system.
India	Has produced British and Russian aircraft under licence. Have designed jet fighter with U.K. engines. Will probably develop a supersonic version.	Small.	Indian high altitude rocket firings have so far used rockets made available by other powers. May develop her own missile in future.	Has bomber force based on British Canberra light bomber which could be given a nuclear strike role for small nuclear weapons.
Italy	Small - reliant on foreign engines.	Small.	Small - modest programme for two-stage sounding rocket.	

Cont.....

Cont... Table 13

Country	Aircraft Industry	Electronics Industry	Missile Industry	Remarks
Japan	-	Large - would be no difficulty in developing guidance systems for missiles.	Most ambitious of non-nuclear powers. Has developed series of high altitude sounding rockets with potential ceilings up to 11,000 miles.	Has basis for the rapid development of long-range missile similar to U.S. Minuteman. Hard to see why this development has taken place unless it is to give a military option. Will probably soon start a space programme.
Sweden	Well developed. Has very advanced interceptor, using U.K. engines built under licence.	Advanced - could rapidly develop a missile guidance system.	Well-developed. Has bombardment missile which can be fired from aircraft against land targets. Also has missile using a jet engine.	If Sweden decides to go nuclear will probably develop tactical weapons only.

rockets so that it can make minor manoeuvres after the main booster rocket has cut out. Travelling at an altitude of 600 to 800 miles it could make a series of course and speed changes, ejecting a warhead each time at different targets. Because of the altitude these targets could be hundreds of miles apart and several degrees of longitude or latitude to either side of the trajectory. It is claimed that the vehicle can carry up to 20 kiloton-size warheads. Each will have its own guidance system programmed to take it to a specific target.

In connection with these and similar weapons Article 4 of the Outer Space Treaty, approved by the U.N. in December 1966, should be noted. This states that "States parties to the treaty undertake not to place in orbit around the earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies or station such weapons in outer space in any other manner."

7. NUCLEAR EXPLOSIONS FOR CIVIL APPLICATIONS

In New Mexico, U.S.A., during December 1967, the U.S.A. set off the first nuclear explosion for civilian purposes. The project was sponsored jointly by the U.S. Atomic Energy Commission and the El Paso Natural Gas Company. A 26-kiloton nuclear device was detonated 4240 ft below the surface of the ground; the purpose of the explosion was to increase natural gas output. The blast was intended to shatter a portion of the 285 ft thick layer of gas-bearing sandstone lying beneath the Leandro Canyon. It was predicted that this would release gas that was tightly locked within the rock. It will not be possible to determine the success of the operation for several months. It remains to be seen if the gas released is sufficiently free from radioactive contaminants to be usable without extensive, and expensive, purification. If this experiment is commercially successful it may stimulate many further nuclear explosions to tap the huge reserves of natural gas locked beneath the surface of the earth.

APPENDIX I

DRAFT TREATY ON THE NON-PROLIFERATION OF NUCLEAR WEAPONS

The States concluding this Treaty, hereinafter referred to as the "Parties to the Treaty".

Considering the devastation that would be visited upon all mankind by a nuclear war and the consequent need to make every effort to avert the danger of such a war and to take measures to safeguard the security of peoples.

Believing that the proliferation of nuclear weapons would seriously enhance the danger of nuclear war.

In conformity with resolutions of the United Nations General Assembly calling for the conclusion of an agreement on the prevention of wider dissemination of nuclear weapons.

Undertaking to co-operate in facilitating the application of International Atomic Energy Agency safeguards on peaceful nuclear activities.

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.

Affirming the principle that the benefits of peaceful applications of nuclear technology, including any technological by-products which may be derived by nuclear-weapon States from the development of nuclear explosive devices, should be available for peaceful purposes to all Parties to the Treaty, whether nuclear-weapon or non-nuclear-weapon States.

Convinced that in furtherance of this principle, all Parties to this Treaty are entitled to participate in the fullest possible exchange of scientific information for, and to contribute alone or in co-operation with other States to, the further development of the applications of atomic energy for peaceful purposes.

Declaring their intention that potential benefits from any peaceful applications of nuclear explosions should be available through appropriate International procedures to non-nuclear-weapon States Party to this Treaty on a non-discriminatory basis and that the charge to such Parties for the explosive devices used should be as low as possible and exclude any charge for research and development.

Declaring their intention to achieve at the earliest possible date the cessation of the nuclear arms race.

Urging the co-operation of all States in the attainment of this objective.

Desiring to further the easing of international tension and the strengthening of trust between States in order to facilitate the cessation of the manufacture of nuclear weapons, the liquidation of all their existing stockpiles, and the elimination from national arsenals of nuclear weapons and the means of their delivery pursuant to a treaty on general and complete disarmament under strict and effective international control.

Noting that nothing in this Treaty affects the right of any group of States to conclude regional treaties in order to assure the total absence of nuclear weapons in their respective territories.

Have agreed as follows:

ARTICLE I

Each nuclear-weapon State Party to this Treaty undertakes not to transfer to any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over such weapons or explosive devices directly, or indirectly; and not in any way to assist, encourage, or induce any non-nuclear-weapon State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, or control over such weapons or explosive devices.

ARTICLE II

Each non-nuclear-weapon State Party to this Treaty undertakes not to receive the transfer from any transferor whatsoever of nuclear weapons or other nuclear explosive devices or of control over such weapons or explosive devices directly, or indirectly; not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices; and not to seek or receive any assistance in the manufacture of nuclear weapons or other nuclear explosive devices.

ARTICLE III

(International Control)

ARTICLE IV

Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II of this Treaty, as well as the right of the Parties to participate in the fullest possible exchange of information for, and to contribute alone or in co-operation with other States to, the further development of the applications of nuclear energy for peaceful purposes.

ARTICLE V

1. Any Party to this Treaty may propose amendments to this Treaty. The text of any proposed amendment shall be submitted to the Depositary Governments which shall circulate it to all Parties to the Treaty. Thereupon, if requested to do so by one-third or more of the Parties to the Treaty, the Depositary Governments shall convene a conference, to which they shall invite all the Parties to the Treaty, to consider such an amendment.

2. Any amendment to this Treaty must be approved by a majority of the votes of all the Parties to the Treaty, including the votes of all nuclear-weapon States Party to this Treaty and all other Parties which, on the date the amendment is circulated, are members of the Board of Governors of the International Atomic Energy Agency. The amendment shall enter into force for all Parties upon the deposit of instruments of ratification by a majority of all the Parties, including the instruments of ratification of all nuclear-weapon States Party to this Treaty and all other Parties which, on the date the amendment is circulated, are members of the Board of Governors of the International Atomic Energy Agency.

3. Five years after the entry into force of this Treaty, a conference of Parties to the Treaty shall be held in Geneva, Switzerland, in order to review the operation of this Treaty with a view to assuring that the purposes and provisions of the Treaty are being realized.

ARTICLE VI

1. This Treaty shall be open to all States for signature. Any State which does sign the Treaty before its entry into force in accordance with paragraph 3 of this Article may accede to it at any time.

2. This Treaty shall be subject to ratification by signature States. Instruments of ratification and instruments of accession shall be deposited with the Governments of   , which are hereby designated the Depositary Governments.

3. This Treaty shall enter into force after its ratification by all nuclear-weapon States signatory to this Treaty, and   other States signatory to this Treaty, and the deposit of their instruments of ratification. For the purposes of this Treaty, a nuclear-weapon State is one which has manufactured and exploded a nuclear weapon or other nuclear explosive device prior to January 1, 1967.

4. For States whose instruments of ratification or accession are deposited subsequent to the entry into force of this Treaty, it shall enter into force on the date of the deposit of their instruments of ratification or accession.

5. The Depositary Governments shall promptly inform all signatory and acceding States of the date of each signature, the date of deposit of each instrument of ratification or of accession, the date of the date of the entry into force of this Treaty, and the date of receipt of any requests for convening a conference or other notices.

6. This Treaty shall be registered by the Depositary Governments pursuant to Article 102 of the Charter of the United Nations.

ARTICLE VII

This Treaty shall be of unlimited duration.

Each Party shall in exercising its national sovereignty have the right to withdraw from the Treaty if it decides that extraordinary events, related to the subject matter of this Treaty, have jeopardized the supreme interests of its country. It shall give notice of such withdrawal to all other Parties to the Treaty and to the United Nations Security Council three months in advance. Such notice shall include a statement of the extraordinary events it regards as having jeopardized its supreme interests.

ARTICLE VIII

This Treaty, the English, Russian, French, Spanish and Chinese texts of which are equally authentic, shall be deposited in the archives of the Depositary Governments. Duly certified copies of this Treaty shall be transmitted by the Depositary Governments to the Governments of the signatory and acceding States.

In witness whereof the undersigned, duly authorized, have signed this Treaty.

FIRST PUGWASH SYMPOSIUM

"Control of Peaceful Uses of Atomic Energy with Particular Reference to Non-proliferation"

D. Vital (Israel) 1 - 3

NUCLEAR OPTIONS AND THE LONG-TERM VIABILITY OF A NON-PROLIFERATION TREATY

It is not clear yet whether the most recent draft of the proposed non-proliferation treaty will be approved by all the seventeen delegations to the Geneva Disarmament Committee; but it is more than likely that if, at long last, a formal treaty does emerge from the ENDC it will differ only marginally, if at all, from the text that Russia and the United States have already approved. Much labour and thought have been devoted to the ENDC and the results, so far, are important. Given contemporary international circumstances there is really very little to suggest that a tougher and more convincing document could have been devised and it may therefore seem both churlish and unreasonable to subject the concept of non-proliferation as expressed in the draft treaty to yet another examination. But the excuse for doing so - if excuse be needed - is that the draft treaty, even if generally accepted, will not and cannot fully dispose of the question of the further proliferation of nuclear weapons. Nor, of course, does it do more than touch upon the graver and actual (as opposed to hypothetical) dangers posed by the existing five nuclear arsenals.

Like all formal international agreements, the non-proliferation treaty represents an attempt to arrest, or at least slow down, the processes of change - political, military and, in this case, technological too. Few such attempts have been more than marginally successful in the past; and so even if the subject matter of the treaty is itself without precedent there are at least prima facie grounds for scepticism about its long-term prospects. In particular we cannot really afford not to look as closely as we know how at those factors which may be expected to work against it over the years. Here the question of those options on the production of weapons which are likely to be retained by the potential nuclear powers may be thought crucial.

The question of options has two aspects: a scientific or technological and a political or strategic. The first aspect is doubtless very complex and it is a fair question whether any but a physical scientist dare say anything at all about it. But it does appear that an important distinction must be drawn between those states which are already civil nuclear powers of some importance and those that are not. And further, that if we concentrate on the first category of states - as it is proposed to do in this paper - there appears to be nothing in the provisions of the treaty that would impose, in practise, an abandonment of such options as the potential military nuclear powers already possess. Indeed, it would still appear to be possible for some or all of them to improve their options somewhat - by the formation of enlarged and more expert scientific and technological cadres, for example - without any overt or covert violation of the treaty.

It is, of course, true that an undertaking by some of the powers which are capable of producing nuclear weapons (and appropriate delivery systems) not to do so, while other powers proceed with the production and perfection of weapons unhindered by the treaty may be thought to put the former at a heightened disadvantage relative to the latter. Nevertheless, this state of affairs will approximate pretty closely to that which obtains today - which only underlines the fact, if further emphasis were needed, that in terms of engineering, as opposed to policy planning, the treaty will not really represent a very radical change from the present. And it is ind ed as a measure designed to help protect us from new dangers, rather than as one coping with those with which we are already familiar that its acceptance has already been advocated.

But if there is nothing in the provisions of the treaty to eliminate or even very seriously diminish the ability of the potential nuclear powers to retain technological options, there is, by the same token, nothing to prevent the retaining of what might be termed politico-military options either. By this is meant, esentially, the maintenance of continuous political, military and technological contingency planning during the life-time of the treaty such

such that in the event of a new view of the matter being taken, it will be possible to take up the technological options with some speed and efficiency. This is, after all, no more than is provided for under the terms of Article VII.[1] So leaving aside, for the moment, the high probability that adherence to the treaty will tend to inhibit and disregarding - as we probably can - the intricate question of covert violation of the treaty, the prospective long-term viability of the projected Geneva system is inescapably a function of the military security of the potential nuclear powers as perceived by their own governments and professional experts.

Now the central characteristic of the system which the draft non-proliferation treaty proposes to establish is that it provides, at any rate implicitly, for 4 classes of states:

a. the existing nuclear powers;
b. potential nuclear powers adhering to the treaty;
c. potential nuclear powers which do not adhere to the treaty;
d. all other powers.

The members of the first class are well known. The members of the fourth class -- states which are not potential nuclear powers because they lack civil nuclear capabilities -- can be excluded from the present discussion. Unless one considers the dissemination of nuclear weapons by members of the first class to those of the fourth -- the least likely of all contingencies -- the retention of options by the latter is not as yet a practical proposition. Nor is it proposed to speculate about the likely behaviour of the third class, those potential nuclear powers which refuse to adhere to the treaty; and still less about the kinds of pressure that might be exerted against them. These are clearly questions of the greatest importance, but they are also markedly beyond the scope of the present discussion.

The crux of the matter of the treaty is rather to be found in the relationship between the members of the first and the second classes. Its key provisions envisage one class of states which will continue to be governed by political and military leaders who both believe they require nuclear weapons and do in fact possess them, and a second class of states which do not and are not to possess them unless their governments are prepared to initiate a great reversal of policy in defiance of the wishes of the most powerful members of the first class. The viability of the treaty system will thus depend first and foremost on two sets of relations: firstly, those subsisting between the various members of the first class; and secondly, the relations between the members of the first class, singly or collectively, on the one hand, and the members of the second class on the other. The viability of the Geneva system, it is contended here, will be a function of the stability of these relations and three difficulties and possible impediments to that stability come immediately to mind.

The first difficulty is that the Geneva system implies and depends upon a perpetuation of the present membership of the first class of powers without, in fact, carrying with it any assurance that it will not be increased by additions from among those who do not adhere to the treaty. It only bars additions from among those who do adhere.

The second difficulty is that it amounts to a substantial reinforcement of both the concepts and the capabilities of what might be called the 1945 United Nations Security Council system under which preponderant power and influence were assumed by the principle members of the World War Alliance within the framework of the most pervasive and important international treaty system of all. We know a great deal today about the weaknesses of the United Nations as an instrument of collective security. Certainly there is now very much less confidence in its efficacy as a means of promoting peace, security and justice than there was in 1945, and for good reason. The Geneva system

1. "......Each Party shall in exercising its National Sovereignty have the right to withdraw from the Treaty if it decides that extraordinary events, related to the subject matter of this Treaty, have jeopardized the supreme interests of this country".

would, however, tend to enhance the special rights, inviobility and authority of the permanent members of the Security Council. Now quite apart from the questions whether this is really what we want, and whether the U.N. collective security system will work any better in the future than it has in the past, it must be asked whether there is any real reason to believe that the present permanent membership of the Council will continue to reflect the substantive membership of the class of Great Powers (however that may be defined) outside the Council in ten or twenty years time. It may already be doubted whether it does today.

But the third difficulty is the most serious of all. It is the tragic paradox inherent in the problem that today, for almost all those commonly judged to be potential nuclear powers,[1] the only context in which the taking up of nuclear options makes even minimal sense is that of contingent confrontation with one of the existing nuclear powers. And it is, ironically, only in this respect that it is difficult to envisage any substantial change over the coming years - if only because the possession of nuclear weapons by one party to a conflict is the most evident and serious incentive to the other party to acquire them. Even granted that today there is good reason to believe that none of the existing nuclear powers contemplates a policy founded on the use or threat of nuclear force there can be no certainty about future governments and future policies. The strategist's ancient distinction between capabilities and intentions has not lost its significance. And there is thus no escaping the agonizing question whether, in the event of a confrontation with any of the existing nuclear states a potential nuclear state would or would not be wise to take up its options.

The strategic aspect of this latter question is one of great complexity. There are very good reasons to believe that the advantages of possessing what might be termed a second or third class nuclear capability in the event of conflict with a state possessing a first class nuclear capability are extremely dubious.[2] But here as in all other problems in nuclear strategy, moral and intellectual factors bulk large and if there is very clearly no certainty about the advantages, neither is there any absolute certainty about the disadvantages. Many of the governments concerned, among them all those that do in fact both feel themselves exposed and are able and willing to provide for their own defence, have therefore chosen a policy of prudence - in fact, a policy of avoiding a firm decision to acquire or not to acquire nuclear weapons, either course having its implicitly lasting and possible unforeseeable consequences. And this prudence, in practice, has led to the retaining of certain nuclear options. Furthermore, the arguments, such as they are, for retaining nuclear options are only marginally less applicable to aligned and protected powers than they are to the unaligned. Even members of the major military treaty systems have had to consider, in the light of the evolution of Great Power strategy in recent years, whether in the event of a reasonably clear prospect of nuclear war - or of any war at all - their present alliances will assist or hinder their own survival. The increasing sophistication of war-heads and delivery systems, the extraordinary and horrendous multiplication of weapons and, latterly, the development of anti-missile defence systems have all done a great deal to de-stabilise the confidence of the allies of the existing nuclear powers in the latter's ability, let alone will, to go to the limit in their defence.

For all these reasons, then, uncertainty, both about the future evolution of international relations and about the ultimate value of nuclear weapons for those who do not possess them already, must be taken as the fundamental datum for a discussion of the prospective viability of a Geneva-type non-proliferation treaty. The greater the success in reducing this uncertainty

1. At the September 1967 Pugwash Conference at Ronneby, Sweden, Sir John Cockcroft pointed out the potential plutonium outputs in 1970 in kilograms per annum of the following: Belgium (2), Canada (650), Czechoslovakia (75), West Germany (235), India (190), Israel (5), Italy (160), Japan (300), Netherlands (10), Pakistan (60), Spain (120), Sweden (120), Switzerland (70) - over and above the existing military nuclear powers. Of these only Israel and, perhaps, Pakistan, should be excluded from the present discussion.

2. The author has discussed this elsewhere in some detail. Cf. D. Vital, <u>The Inequality of States; a Study of the Small Power in International Relations</u>, Clarendon, Oxford, 1967, pp.159-182.

in the desirable direction, the more promising will be the treaty's prospects and the longer its effective life. Would an offer of security guarantees to the potential nuclear power have this effect? Guarantees have been much discussed and it may be that guarantees of some kind will in fact be offered at some stage - particularly if the resistance of some key non-nuclear members of the ENDC to the present draft of the treaty remains unabated. But the crucial question is what, in this context, would constitute effective quarantees; and it is a hard one. So too is the more speculative, but nonetheless vital question of the likely long-term political consequences of granting effective guarantees.

At one level, the effectiveness of security guarantees granted by one state to another would appear to depend to some extent on its military content and legal form. For example, a unilateral undertaking by a guarantor is generally thought to be weaker, and a general unilateral guarantee addressed to no state in particular[1] weaker still, than a clear, bilateral treaty of assistance. But for all their intrinsic significance, such considerations as these can here be set aside. At a more fundamental level of effectiveness, the value of guarantees, whatever their form and whatever the identity of the guarantors, must be assessed in the light of a quite different test: will they be of sufficient force and credibility to cancel out - or be thought to cancel out - the military advantage that nuclear powers possess - or are thought to possess - in the event of confrontation with non-nuclear powers? For however dubious may be the strategic advantages accruing to a minor nuclear power by virtue of its nuclear capability in the event of confrontation with a major nuclear power, it must be evident that <u>certainty</u> of disadvantage is to be found only where the minor power is without any nuclear arms whatsoever. And prudence, as has been suggested, may therefore still appear to dictate an active retention of options. Some specialists believe that two of the five nuclear powers may be said to be close to, if not beyond, the point where they can be deterred effectively by a secondary nuclear power. The least that can be said about their arguments, however, is that many of the opponents of this view remain undismayed and that this in itself is an important component of the equation. But valid or not in its proper context, the superpower-minorpower model of nuclear confrontation is quite inapplicable to the case of further additions to the class of nuclear powers from among those who refuse to adhere to the treaty or eventually withdraw from it.

At first sight, then, there would appear to be two possibilities. One would be a system of negative guarantees, as it were, based upon the nuclear disarmament of the existing nuclear powers themselves. However, apart from the immense technical difficulties such a move would involve, we know well enough that important strategic considerations link nuclear and general disarmament together and that general disarmament is as good as ruled out by the conflicts between the three major powers,[2] to say nothing of those that divide other members of the international community.

The second possibility would be bilateral or multilateral defence agreements over and above those already undertaken in the NATO, Warsaw and other pacts, extended as circumstances might require to unaligned states. But again, we know how reluctant the nuclear powers are, in practise, to extend such guarantees and, indeed, how much the guarantees implicit in existing mutual assistance pacts have already lost in force and credibility. Nevertheless, the fact remains that nothing less than a formal and binding undertaking to go to war in the defence of an adherent to the non-proliferation treaty in the event of its being threatened by a nuclear power and regardless of whether the threat be expressed in terms of nuclear or conventional armaments would really serve. Yet would one of the existing nuclear powers be prepared to risk a confrontation with another nuclear power in defence of a third state which might be no more than peripheral to its own system - or even well beyond it? It appears

1. E.g. President Johnson's 1964 declaration that 'nations not following the nuclear path will have our strong support against threats of nuclear blackmail.'

2. The Geneva draft treaty includes a declaration of intent in this direction, but it is unsupported by any stronger evidence that the powers concerned are proceeding towards that target.

unlikely - a fact which accounts both for the reluctance of the major powers to give such undertakings and for the reserve with which the minor powers concerned have reacted to such half-hearted declarations on the subject as have been made thus far. For the nuclear powers themselves, the major difficulty is surely that once such binding undertakings are made, and, of course, provided they are treated seriously by both parties, the guarantor is liable to become the prisoner of the guaranteed. The power in receipt of the guarantee will, up to a point, be in a position to involve the guarantor power in situations which might lead to war.

Indeed, the closer one looks at this problem of guarantees the more difficult it becomes to conceive of any reasonable solution to it. The problems confronting the potential nuclear power are not limited to the contingency of direct and initial confrontation between it and one of the existing nuclear powers. For many - certainly for most or all of the unaligned states among them - defence thinking is geared equally to the contingency of a confrontation between two of the nuclear powers spilling over, as it were, into their own, narrower, arena. A guarantee by one of the nuclear powers, and certainly a guarantee by two or more, may therefore, in certain circumstances, actually constitute an impediment to the prime national purpose of such states, namely that of emerging from a period of general conflict unscathed.

In short, the problem of guarantees cannot be isolated from the circumstance that, in the final analysis, the major determinant of the existing nuclear powers' external policy is their strategy vis-a-vis each other. Alternatively, no guarantee undertaken by them will be really credible - and therefore have a chance of operating as an effective surrogate for the active retention of options - unless that undertaking is firmly locked into the superpowers' own strategic deadlock in such a way that failure to honour the guarantee would itself trigger off risks of conflict. How might this be done? One method might be the establishment of a system of hostages. If potential nuclear power X fears an attack or threat of attack by nuclear power A, troops of nuclear power B might be stationed on its soil. But, of course, the effect of such an arrangement would be almost indistinguishable from an extension of the existing alliance system and would probably be unacceptable on these grounds alone.

But even assuming that a team of inventive international lawyers, diplomats, and strategists contrived to think of some better arrangement, it remains clear enough that a credible guarantee must carry with it - for the guarantor - the risk of involvement in war. Assuming further that this were indeed acceptable to both parties, what would seem likely to follow the establishment of a credible guarantee system?

There can be no doubt, I think, that the granting of such guarantees will be conditional upon rigorous, if not necessarily public, control of the external policy of the recipient. Certainly, there would have to be some form of control or supervision or right of veto in those matters which bear upon the fulfilment of the guarantee. It is really impossible to believe that without such control guarantees of any practical significance be granted. And if indeed they were, this alone might be expected to reduce the credibility of the guarantee not only in the eyes of the recipient, but, and much more significantly, in the eyes of the recipient's potential opponent.

The validity of the general proposition underlying this argument is not one which can be easily demonstrated, if at all, even though its converse would seem utterly implausible. But at all events, it is impossible to believe that no political/military quid pro quo whatsoever will be required of the recipient by the guarantor state or states. And furthermore it seems reasonable to suppose that any quid pro quo granted would have to be, in some sense, proportionate to the magnitude of the undertaking implicit in the guarantee. This would surely have the effect of converting the recipient into an ally at best, and at worst into a vassal - at any rate for so long as there is no major change in the substance of the two great components of the potential nuclear powers' total situation: the fact that the existing nuclear powers are themselves in strategic deadlock; and that such military utility as nuclear weapons might have for them is functionally related to the nuclear armaments of those who would, in principle, have to provide the guarantees. All in all, then, there are grounds for anticipating that effective guarantees are unlikely to be fully acceptable and, if for that reason alone, perhaps equally unlikely to be proffered.

If this conclusion seems excessively pessimistic, it is as well to note that in practice the situation during the lifetime of the treaty would probably be very similar to that which obtains at the present time. The security of many of the key potential nuclear powers is maintained today w thout benefit of undertakings by the Great Powers. Those concerned tend to prefer it that way and, after all, there appears to be general understanding of the delicate implications of this state of affairs. If adherence to the treaty, even without guarantees, will serve to inhibit the taking up of nuclear options by those among the adherents who are materially capable of doing so, then clearly something additional of great importance will have been achieved, at slight cost to the Great Powers and, possibly, with revolutionary consequences for the future evolution of the international system. There is, instead, no reason to suppose that the treaty will not have this inhibitory effect, at any rate for a time and proponents of the treaty are clearly relying upon it. To that extent, then, the post ratification situation may be thought an improvement over that of today. But there is also a debit side to the balance of relative advantages and disadvantages. It is that if the international scene changes greatly in coming years and the corresponding strains and fears lead to the available options being taken up by even a minority of the non-nuclear powers, then the advent of such additional nuclear powers is likely to have a much greater political resonance than it would have had otherwise. Nor will the question whether those opting for nuclear weapons act in violation of the treaty or under the terms of Article VII be really decisive in this respect. A critical threshold will have been crossed, a threshold made clear and evident, if not actually established, by the treaty itself.

In sum, the exercise in selective arms limitation embodied in the treaty is not without certain risks. This is surely not in itself a defect, but nor would it be wise to overlook the fact. Equally, the achievement of Russo-American agreement on the text of the draft treaty is certainly a major event, but given that there is no clear and binding provision for the superpowers' own disarmament, or even for a limitation of their existing arsenals, the fact of agreement is not quite as fateful as it might at first appear. Indeed, it cannot be stressed too firmly or too often that the key to the problem of the spectre of nuclear warfare still lies squarely in the hands of the existing nuclear powers themselves. If, therefore, the effect of the non-proliferation treaty, however worthy the intentions underlying it, is to shift attention away from this fact it will have done us all a profound disservice. But in any case, those states which consider themselves menaced by the existing nuclear powers are unlikely to forget who, today, and who alone, is capable of waging nuclear war. So long as the existing nuclear arsenals form part of potential nuclear powers'political and military environment - and, therefore, of their calculations - they are unlikely to fully abandon such technical options as they possess. And by the same token the very real possibility and dangers of further proliferation will not in the least be ended by general approval of the treaty. The heart of the matter, it seems, will remain suspended for many years to come.

FIRST PUGWASH SYMPOSIUM

"Control of Peaceful Uses of Atomic Energy with Particular Reference to Non-Proliferation"

P. L. Ølgaard (Denmark) 1 - 4

THE US-USSR DRAFT TREATY ON NON-PROLIFERATION - WILL IT WORK?

1. INTRODUCTION

The great majority of non-nuclear weapon nations (hereafter called non-nuclear nations) have on many occasions expressed their concern about the dangers of nuclear proliferation and stressed the need for the early conclusion of a non-proliferation treaty. It is important to understand, however, that these countries are not willing to sign any non-proliferation treaty. The conclusion of a treaty that is likely to last only for a rather limited time, say ten years or less, can be in the interest of neither the non-nuclear nor the nuclear weapon states (hereafter called nuclear states). To make it a lasting treaty it is essential to take into account the legitimate interests of both the non-nuclear and the nuclear nations and also the scientific facts of life.

2. REQUIREMENTS OF A NON-PROLIFERATION TREATY

Any non-proliferation treaty has as its object the prevention of the emergence of new nuclear powers. Thus, such a treaty will basically put a greater restraint on the non-nuclear nations, the have-nots, than on the nuclear powers, the haves. To make up for this lack of balance, the following conditions must be fulfilled in order that the treaty may be acceptable, and remain so, to the non-nuclear nations:

(1) The non-nuclear nations must have the right without discrimination to use atomic energy for peaceful purposes. There is every indication that atomic energy will play a major role in the future energy production of the world, and it will obviously be unacceptable to the non-nuclear countries not to have the same opportunities in this field as the nuclear nations.

(2) The treaty must take into account the legitimate security interests of the non-nuclear countries, i.e. it must provide such guarantees that a non-nuclear country will not be in a better security position if, instead of signing the treaty, it acquires a nuclear arsenal.

(3) Because of the basic lack of balance of a non-proliferation treaty it is important that the nuclear powers show their good faith by accepting some restraint on themselves. In addition to the guarantees mentioned in (2), this could take the form of arms control measures such as a full test-ban treaty, a decision not to deploy an ABM-system, a reduction in the number of offensive ICBM's or a reduction of the production of special nuclear materials such as tritium and fissile materials for military purposes.

(4) Last, but certainly not least, a non-proliferation treaty must of course be effective, i.e. a non-nuclear nation which signs the treaty must not risk having to face the situation that one of its potential enemies, that has earlier been a non-nuclear signatory country, suddenly becomes a nuclear power. This is a vital point since the treaty gives only rather vague guarantees.

It may, of course, be possible to persuade the great majority of non-nuclear powers to sign a non-proliferation treaty which does not fulfill these requirements, if necessary by the application of political, economic or other types of pressure. But such a treaty is very likely to have a rather limited lifetime since it will not commit the countries under pressure morally - and, it may be argued, not even legally - and once the political power constellation that exerts the pressure is changed, new nuclear powers are likely to emerge rapidly.

It is important, therefore, to evaluate any proposal for a non-proliferation treaty to see to what extent it fulfils the conditions listed above, and in the following the draft treaty submitted by the US and the USSR to the Eighteen Nation Disarmament Conference on January 18th, 1968, is so considered.

3. THE US-USSR DRAFT TREATY AS SEEN FROM A NUCLEAR POWER POINT OF VIEW

Before this draft treaty is discussed from a non-nuclear nation point of view, it seems reasonable to examine how well it protects the interests of the nuclear nations.

It is not surprising that the document appears almost ideal from a nuclear power point of view; after all it has been worked out by the two nuclear superpowers.

The draft treaty forbids the nuclear powers to transfer nuclear weapons, directly or indirectly, to other countries, but no demand for control of observance is introduced (Article I).

Further, the treaty forbids the non-nuclear nations to acquire nuclear weapons in any form. To ensure observance all peaceful atomic energy facilities of the non-nuclear countries will be subject to control by the IAEA, (Articles II and III). However, no control of atomic energy facilities of the nuclear nations is required under the treaty.

The draft opens up the possibility of peaceful applications of nuclear explosions in non-nuclear countries, but performed by a nuclear power (Article V). Since, at the present time, there are no obvious/useful practical applications of such explosions, and since the future prospects of the usefulness of this technique are rather uncertain, there may be those who consider the inclusion of this Article mainly a way of "legalizing" underground nuclear weapon tests.

In Article VI the nuclear (as well as the non-nuclear) powers commit themselves to pursue further disarmament negotiations. However, this commitment is very vague - for example, no indication of when such negotiations are to be initiated is given - and the validity of the treaty is not in any way dependent on whether these negotiations are or are not initiated.

Finally, in Article VIII the nuclear powers are given a veto on any proposal for amendments of the treaty.

From these considerations it is clear that the treaty is very attractive to the nuclear powers. This is of course in itself an advantage, but the importance of this point should not be overestimated. It may be argued that it is unnecessary to have the nuclear countries sign a non-proliferation treaty in which their only real obligation is not to transfer nuclear weapons to others. It is very improbable that they will ever do so anyway, but if the unlikely situation should arise that a nuclear power decided to transfer nuclear weapons to a non-nuclear state, little if anything could be done to prevent it.

4. THE NON-NUCLEAR NATION POINT OF VIEW - PEACEFUL USES OF ATOMIC ENERGY

To the non-nuclear nations the treaty is unfortunately not quite as attractive as to the nuclear powess.

With respect to the non-discriminatory use of atomic energy for peaceful purposes by the non-nuclear nations, Article IV should ensure that this right is not invaded. At the same time Article III calls for control of all nuclear facilities of the non-nuclear countries, and it is by no means obvious that these two provisions are compatible. Therefore this question must be further considered.

The IAEA inspection procedure for nuclear reactor plants is now fairly well established, and it seems that control of this type of facility will not give rise to undue restrictions, since the amount of technical information which must be submitted to the IAEA in connection with inspections of reactors is fairly limited.

The situation is not quite so clear when it comes to fuel fabrication facilities and reprocessing plants. The inspection procedure has not yet been finalized for these types of facilities, but the amount of technical information required must be expected to be quite detailed if the control is to be realistic. It is, for example, necessary to have a thorough knowledge of the processes used in order to assess whether the losses of fissile material that will unavoidably occur are reasonable or could represent a violation of the treaty. But such detailed knowledge of the processes involved might also lead to so-called industrial espionage.

Further it is not unlikely that one or more non-nuclear countries will build there own enrichment plants in order not to be dependent for reactor fuel on supplies of enriched uranium from other countries. They may also do so to secure for themselves the future fuel supply to foreign buyers of their reactors and thereby gain a better position on the reactor export market. As the IAEA has no experience of inspection of this type of plant, it is impossible to decide whether a realistic control system will interfere unduly with the operation of such plants for peaceful and commercial purposes; it is very likely, however, that control will require access to rather detailed technical information.

There are other factors that make it difficult to assess whether IAEA control will interfere unduly with the peaceful uses of atomic energy in the non-nuclear countries. For example, according to the Statute of the IAEA, Article XII, the Agency has the right to demand that any excess of special fissionable materials over what is needed for research and for reactors is deposited with the Agency, in order to prevent stockpiling of these materials.

This right of the Agency raises a number of questions. Where is the fissionable material to be stored? In the country where it is produced, or outside? What guarantee does the country owning deposited materials have that the material is returned promptly when needed for legitimate purposes? Consider the case where one of the IAEA inspectors claims during the inspection that the safeguarding rules have been violated, while his colleagues do not agree with this. If such a situation arises, willmit be possible for the country concerned to have deposited materials returned promptly, or will the return be delayed until further investigations have been performed? In the latter case the possibilities of the non-nuclear countries of selling nuclear fuel may easily be impaired.

The answers to these questions - and there are others - will for a great part decide whether the non-nuclear countries will have the same opportunities as the nuclear countries in the reactor and nuclear fuel business.

It is quite possible that IAEA control in connection with a non-proliferation treaty will not interfere unduly with the peaceful uses of atomic energy in the non-nuclear states, but unfortunately too little is known about IAEA safeguards for a realistic and fair evaluation of this problem to be made. It is therefore understandable that some non-nuclear countries hesitate to accept IAEA control and use this as an argument against the non-proliferation treaty.

5. THE NON-NUCLEAR POINT OF VIEW - GUARANTEES

As regards guarantees, the draft treaty is quite unsatisfactory since no guarantee provision whatsoever has been included. The question of guarantees is not even mentioned in Article VI, which deals with future disarmament negotiations.

It may be said that some form of guarantee arrangement arrangement does already exist for the non-nuclear countries since President Johnson stated in October, 1964, that "the nations that do not seek national nuclear weapons can be sure that if they need our strong support against some threat of nuclear blackmail, then they will have it". But what is strong support? It may range from warm moral support to direct military assistance; unfortunately the US government has been reluctant to define strong support more specifically. Further the assurance covers only nuclear blackmail. Several of the countries that might go nuclear will do so to deter a non-nuclear enemy much stronger in conventional arms, not to deter a nuclear state. And in this case the US assurance is of no help. Finally, many non-nuclear countries will require guarantees from a number of countries, including the two superpowers. The political situation of the world is not stationary, and the power constellation is going to change, thus a guarantee given by only one nation may be credible today, but not tomorrow.

In March 1966, Mr. McNamara said during a hearing on non-proliferation:

"We must not conclude that the conditions that make proliferation appear desirable for some countries are not present today. They are. They are going to be present tomorrow as well. The non-proliferation agreement must recognize that element of reality. If it does, it must be associated with some form of assurance to these nations which have a reason for acquiring nuclear weapons, but but which under the terms of the treaty presumably will agree not to acquire them".

The draft treaty is not associated with any forms of assurance.

6. THE NON-NUCLEAR POINT OF VIEW - RESTRAINTS ON THE NUCLEAR POWERS

According to Article VI of the draft treaty all parties to the treaty undertake to pursue negotiations on measures regarding cessation of the nuclear arms race and disarmament. As mentioned already in section 3, the formulation of this Article is, however, very vague. It does not go beyond resolutions adopted in the UN, and disarmament negotiations are already under way in the ENDC in Geneva.

It may be of interest to consider what arms control measures might result from such negotiations and to evaluate the chances that they are agreed upon.

One possibility is a comprehensive test-ban treaty. The chances that the nuclear powers will agree to stop underground tests are, however, small. The superpowers obviously fear that a comprehensive test-ban treaty will not allow them to retain the staff of their weapon laboratories and thus to continue the development of improved nuclear weapons. This problem is made more acute by the USSR deployment of an ABM system and the US decision to do the same. In this context it may be mentioned that the USAEC has recently asked for a significant increase of funds for nuclear weapon development, and part of these funds is to be used on new underground testing sites. It may also be noted that only three out of the present five nuclear powers have signed the present test-ban treaty.

Another possible arms control measure is a decision by the nuclear superpowers to refrain from the deployment of ABM systems and/or to reduce their number of offensive ICBM's. There has already been contact between the two nuclear superpowers on this subject, but little came of it, and since then the US has decided to deploy a thin ABM system. Even though this development could theoretically be reversed, it does not seem very likely that it will.

A third possibility is that the nuclear powers agree to reduce or stop their production of special nuclear materials, i.e. fissile materials and tritium, for military purposes. It is very unlikely that France and China will accept such a proposal since both countries are building up their nuclear arsenals. The remaining nuclear powers have already reduced their production of fissionable materials, but the reason is primarily that their stocks of these materials are so large that they will easily cover the weapon demands in any foreseeable future, and hence there is no point in maintaining production at full capacity. On the other hand these nuclear powers are not likely to accept a full stop of the production of special materials for military purposes since this would prevent them, in the long run, from maintaining their nuclear fleets. The use of reactor fuel for nuclear naval vessels is a military application too, and the nuclear powers are not likely to accept such a situation even though it has the desirable features that it would only demand control of production facilities and that it would only come into effect gradually.

7. THE NON-NUCLEAR POINT OF VIEW - EFFECTIVE PREVENTION OF PROLIFERATION

Finally there is point (4): the treaty must effectively prevent nuclear proliferation, and the question is: will the draft treaty do so?

If signed by all major powers, it will undoubtedly prevent the emergence of true nuclear powers with an appreciable number of sophisticated nuclear weapons, since it is not possible to develope advanced weapons without test explosions and since IAEA control should be able to prevent large scale stockpiling of fissile materials for weapon purposes.

But this is not the problem. Today there is hardly any non-nuclear nation which would be able to become a major nuclear power in a foreseeable future, even if there was no non-proliferation treaty, and none of the present non-nuclear powers will be able to develop a nuclear arsenal that could deter the superpowers.

The danger of proliferation today is the emergence of what might be called the primitive nuclear powers with a limited stock of untested nuclear weapons, which may not have very high yields, but will still be nuclear weapons in, say, the one to twenty kiloton range. The primitive nuclear powers will not be able to deter any nuclear power, but this is not the intention. The purpose of acquiring primitive nuclear weapons is to deter unfriendly non-nuclear powers, and in this case, it is also unnecessary to possess sophisticated delivery vehicles; conventional military aircraft will suffice.

The problem therefore is: Will the treaty be able to prevent the emergence of primitive nuclear powers?

The answer is: No.

During the next ten to twenty years a large number of countries will build nuclear power plants. These plants will produce plutonium, which will be extracted in reprocessing plants. Even though IAEA control will prevent large scale stockpiling of this plutonium under national control, it will not prevent research concerning the physical, chemical and metallurgical properties of plutonium and the development of the methods necessary for production of materials for nuclear weapons. All this development work can easily be performed under the pretext of studies of the peaceful uses of atomic energy. Nor can IAEA control prevent the plutonium produced from being used in zero-energy fast reactors, in which the plutonium is kept in a form suitable for rapid conversion into primitive nuclear weapons. A zero-energy fast reactor, built to simulate the conditions in large diluted cores to be used in fast power reactors, may contain several hundred kilograms of plutonium, and this plutonium could in a few weeks or less be transformed into, say, 50 nuclear weapons, which would certainly suffice for any primitive nuclear power. In theory at least it is even possible to build small, compact fast research reactors, the fuel of which might be used directly as the fissionable charge in a nuclear weapon. And many interesting experiments of general reactor physics interest can be made with this type of reactor.

To make a primitive nuclear weapon with plutonium it is not sufficient to have the fissile material available. It is also essential to master the implosion technique. However, this technique is applied to an increasing extent for military (non-nuclear), for scientific and even for industrial purposes, and the amount of literature published on it is steadily increasing. It is consequently very likely that any reasonable industrialized country will be able to master this technique, if it so desires, after a development period of some years. And it will be extremely difficult to detect whether a country is developing this technique for nuclear weapon purposes.

It may be objected that the plutonium produced in power reactors is not very suitable for weapon production because of its high Pu^{240} concentration. However, there are many indications that this difficulty can be overcome if the implosion technique is mastered to a sufficiently high degree of perfection. The yields may be reduced somewhat, and the chances of a fizzle may increase, but the weapons will be nuclear weapons after all, and they will be considerably cheaper than those produced from the so-called weapon-grade plutonium. It may be appropriate to quote in this connection the chairman of the USAEC, Dr. Seaborg, who said during a hearing in 1966: "We believe that a number of nations, using the plutonium that they would produce in their power reactors, have the technical equipment and capability....to produce bombs in the course of a few years....".

It mau also be mentioned that if a country possesses a uranium separation plant capable of producing highly enriched uranium, the technical problems connected with weapon production are reduced considerably.

Therefore the only one hundred per cent effective way of preventing the emergence of primitive nuclear powers seems to be to deny the non-nuclear powers the possession of highly enriched uranium and plutonium. This would not be acceptable to the non-nuclear nations since it would mean that they could not be allowed to build reprocessing plants or isotope separation plants and, most important, to develop and build fast power reactors. Since the fast power reactor is considered to be <u>the</u> reactor of the future, such conditions would represent a gross discrimination against the non-nuclear countries.

8. CONCLUSIONS

From the consideration given above it is obvious that the US-USSR draft treaty does not fulfil the legitimate requirements of the non-nuclear countries as outlined in section 2, since

- the introduction of IAEA Safeguards may discriminate against the peaceful uses of atomic energy in the non-nuclear countries; before the IAEA inspection procedurs for all types of atomic energy facilities have been finalized, no conclusion can be drawn with respect to this point,
- the draft treaty contains no guarantee provision, nor does it foresee any later introduction of such guarantees,
- the draft treaty does not contain any assurance that the nuclear powers will accept any restraint on themselves,
- the draft treaty will not be able to prevent the emergence of primitive nuclear powers.

It should be pointed out that it may not be possible to produce a non-proliferation treaty that fulfils all the requirements of section 2. If the treaty does not discriminate against the peaceful uses of atomic energy of the non-nuclear countries, it will be very difficult technically to prevent the emergence of primitive nuclear powers. However, if a sufficiently credible guaranteesystem is included in the treaty, this will remove the incentive for all non-nuclear countries to become nuclear powers. The need for restraints on nuclear powers in connection with a non-proliferation treaty will also be reduced if a sufficiently credible guarantee arrangement, which will obviously involve the nuclear powers first of all, is included in the treaty.

It may be argued that only a limited number of non-nuclear countries have pressed the point of guarantees, which is therefore not essential. But this is not correct. The reason why only a limited number of countries have pressed this issue is that most of the countries that in the past have felt uneasy about their security have concluded defence agreements with other countries, usually including one or more nuclear powers. Consequently they feel no immediate need for additional guarantees. However, the power constellations of the world are changing continuously, and a defence agreement that is satisfactory today may not be so tomorrow. Further it is getting easier and cheaper to become a primitive nuclear power. Therefore, the non-nuclear countries that in the future decide to terminate existing defence arrangements with others may be very much tempted, in the vacuum created by this decision, to acquire nuclear weapons of their own.

If only one or two non-nuclear countries go nuclear, the absence of guarantees is most likely to create a chain reaction among the near-nuclear powers whereby the number of nuclear powers will increase rapidly, and this would be the end of non-proliferation. With guarantees a non-proliferation treaty should be able to survive the emergence of one or two new nuclear powers; the probability of such emergence, with guarantees, would be much smaller.

Thus the only way of making a lasting non-proliferation treaty is to include credible guarantee arrangements whereby the incentive for a non-nuclear power to become nuclear is removed. Since such arrangements are totally absent in the draft treaty, the answer to the question posed in the title of this paper is from a long-term point of view:

<u>THE US-USSR DRAFT TREATY ON NON-PROLIFERATION WILL IN ALL PROBABILITY NOT WORK</u>

It is also worth mentioning that arms control measures, like the draft treaty, which mainly puts restraints on the non-nuclear countries, will easily compromise further disarmament measures in the eyes of the non-nuclear countries. And it should also not be forgotten that the security of the world depends first of all on the nuclear superpowers. If they are not willing to restrain themselves, no arms control agreement will help. After all they alone have the Armageddon capability.

9. AN ALTERNATIVE APPROACH TO A NON-PROLIFERATION TREATY

The conclusion given above is rather depressing, but of course it raises the question: Is there a better approach to a non-proliferation treaty?

As argued above, a lasting non-proliferation treaty must assure that the inspection system agreed upon does not discriminate against the peaceful uses of atomic energy in the non-nuclear countries. The IAEA safeguarding procedures are not yet established for all types of atomic energy facilities, and it will probably be a few years before this is the case. Until these procedures are finalized and agreed upon by the countries involved, it is not reasonable to include IAEA control in a non-proliferation treaty. To do so would be the same as to sign a blank cheque, and that is very dangerous.

Further, the introduction of a credible guarantee arrangement will demand intricate negotiations, not least between the nuclear and the non-nuclear powers. Considering the present political climate in the world, it is very likely that such negotiations could only be brought to a satisfactory conclusion after a period of some years.

On the other hand danger of proliferation is acute, and it may be too late if a treaty does not come into effect until several years from now. What the world needs is therefore a period of negotiation during which one can be assured that proliferation will not take place.

A first step of a possible solution to this problem would be the conclusion of a preliminary non-proliferation treaty, the substance of which should be Articles I and II of the draft treaty. Hence it would not require compulsory control of any parties to the treaty. Further the treaty should be valid for a period of five years only. During this period the IAEA safeguarding procedures should be finalized and agreed upon. Also the guarantee arrangements to be included in the final treaty should be negotiated.

Provided these negotiations are completed successfully, a final non-proliferation treaty should be prepared and signed as a second step. If the five years do not suffice for the successful completion of the negotiations, the preliminary treaty should, under a provision contained in it, be prolonged for a shorter period, say up to another five years - provided the prospects of reaching agreement on the control and guarantee question look reasonably promising.

Such a procedure seems to have a number of advantages.

It should be possible to conclude such a preliminary treaty in the immediate future and thereby make some concrete progress towards a lasting non-proliferation treaty.

It would be very difficult for any non-nuclear country not to sign such a preliminary treaty since it has a very limited duration and since it does not involve any compulsory inspection.

It would provide a reasonable period for finalizing an IAEA safeguarding system and agreement on a credible guarantee arrangement.

It would ultimately allow the conclusion of a non-proliferation treaty that takes into account the legitimate interests of both the nuclear and the non-nuclear countries.

It should be noted that the IAEA safeguards will of course continue, but only on the present, voluntaty basis. It is important that the IAEA is given the opportunity to gain inspection experience in order to allow the establishment of a safeguarding procedure acceptable to all parties involved.

The two nuclear superpowers may not immediately find this approach very acceptable since they may still hope to be able to press through their treaty proposal. However, when the draft treaty was submitted to the ENDC in Geneva, it did not get a very enthusiastic reception, and the superpowers may soon realize that it will not be easy to reach agreement on their proposal. In this case it should be possible for the non-nuclear powers to persuade the superpowers to shift their line of approach. Should this not be feasible, the non-nuclear powers might even agree among themselves on a preliminary non-proliferation treaty without control and then demand inspection and guarantee negotiations with the nuclear powers. In this case, what could the nuclear powers do other than accept?

It must be in the interest of all countries, nuclear as well as non-nuclear, who are concerned about the dangers of proliferation to have a lasting treaty. A treaty lasting only for a limited period will give rise on its termination to a rapid increase in the number of nuclear powers, and the situation might then be worse than if there had been no treaty at all.