Fondazione per la Pace
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«Alcide De Gasperi»
– Roma –

S T E S

SCIENZIATI E TECNOLOGI
PER L'ETICA DELLO SVILUPPO
– Roma –

SIMPOSIO INTERNAZIONALE
SULLA

CONVERSIONE DELLE TESTATE NUCLEARI
PER USI PACIFICI

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CONVERSION OF NUCLEAR WARHEADS FOR PEACEFUL PURPOSES
Fondazione per la pace e la cooperazione
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Scienziati e tecnologi per l'etica dello sviluppo
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FONDAZIONE PER LA PACE
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INTERNAZIONALE
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PER L'ETICA DELLO SVILUPPO

(1)

International Symposium

on

"CONVERSION OF NUCLEAR WARHEADS FOR PEACEFUL PURPOSES"

Palazzo Doria - Rome

June 15-17, 1992

" The feasibility studies of the Italian Working Group"

by Prof. M. SILVESTRI

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International symposium
on

"CONVERSION OF NUCLEAR WARHEADS FOR PEACEFUL PURPOSES"

Palazzo Doria, Rome
june 15 - 17 1992

prof. Mario Silvestri

A few considerations arising from the feasibility study of the Italian working group on the conversion of nuclear weapons into useful energy.

It has been repeated so many times that the number of nuclear warheads existing in the world (> 55 000) is out of proportion with any military use, which could be made of nuclear explosives. On the other hand a process of nuclear disarmament capable of cancelling nuclear explosives from the face of the earth would be utopian, because the human memory cannot be erased, and for a great industrial power to rebuild a stock of a few nuclear weapons would require a time no longer than several month, one tenth of the time required by the United States to build the first atomic bombs in 1942 - 1945. But a possible residual nuclear capability would be so small, that we can assume that the process of nuclear disarmament involves the totality of the nuclear warheads.

It is true that 95 % of nuclear warheads are detained by the United States and the ISC, but their destructive potential is so great that also France, U.K. and China should be associated to the disarmament process in the near future, because their stocks, although small in comparison with those in the hands of the greatest powers, still possess a destructivness beyond any acceptable level. If we speak therefore of the USA and of the former URSS only, it is for sake of simplicity, but certainly not because the other military nuclear powers should be neglected as unimportant.

It is common kowledge, albeit non supported by any official document, that the total amount of nuclear explosives existing on the earth consists approximately of 1 000 metric tons of almost pure U-235 (HEU) and of 200 tons of almost pure Pu-239. Both U-235 and Pu-239 (as much as their isotopes U-233 and Pu-241) have equal energy values, from a practical point of view (1 Mwd(thermal)/g) when used as nuclear fuels, while their explosive capacity could be very different. Indeed they can be used as A-bombs (with a yield much less than one) or as triggers for H-bombs: and in this case their yield is practically unlimited. For reasons I really do not know, to each nuclear weapon is attributed an equivalent explosive force between 0.5 to 1 MTNT (Million tons TNT equivalent), which is somewhat higher than their energy equivalent.

In the study herewith presented, and prepared by a working group assembled with ENEL-ENEA and Ansaldo personnel (mostly engineers) an attempt was made to evaluate the difficulties existing along the path for a peaceful utilization of those isotopes (U-235 and Pu-239), mostly used as explosives, to be converted into fuels for the civilian reactors operating in the world. The energy content of their stock is such as to produce the total amount of electrical energy required by the world in one year. However nuclear power provides only 18 % of the electric energy requirements. Therefore, in the optimistic case that any of the civilian reactors now in operation would be capable of accepting those fuels, their burning would require almost 6 years, whithout taking into consideration the disruption procured to the uranium mining industry and to the economy of the enrichment plants. These considerations are obvious and trifling, but they shed light on the fact that nuclear demobilization is not a trifling problem at all and its attainment will require a major fraction of the next half century.

The problems are more economical than technical, where U-235 is concerned. Of course in the USA and ISC it could be possible to use a U-235 fuel at its maximum purity, with a seed and blanket arrangement. A blanket of thorium, with the accompanying production of U-233, could substantially increase the energy yield of each gram of U-235. For non nuclear nations (military speaking) of course the natural procedure would be dilution below a safety level internationally agreed. However, even in this case, at least three technical options, are open: dilution with natural uranium (U-235 ≈ 0.72 %), dilution with depleted uranium (U-235 ≈ 0.25 %) and dilution with very slightly enriched uranium. The main point is economical: how to coerce the civilian reactors to sip those fuels, correctly streched in time, in a way best suited in order not to disturb the uranium industry. Our elementary calculations show that a clever management of this operation could provide a net benefit of 50 to 60 billion $.

Much more complex is the problem of burning or discarding plutonium. A relevant experience has been made in France and in Japan with MOX fuel elements. From this point of view it is a pity that the United States interrupted their in-core burnig of MOX fuel elements 15 years ago. A technological skill is easily lost, and difficult to find back. We in Italy unfortunately know best how it happens. The so called 5 year-moratorium has razed to the ground our domestic nuclear expertise, which had required 30 years to be moulded and would require thirty years more to be rebuilt.

From this point of view it seems to me that the problem of nonproliferation has been somewhat exagerated. Handling of plutonium, and likewise toxic materials is not an easy task. Even taking as an example the Iraqi effort to have an atom bomb, it required more than 10 billion $, *not* to have the atom bomb. Anyhow for a small nation to have a single or a few nuclear weapons is meaningless. The power of these weapons is always a negative one: deterrence. If deterrence fails, the nuclear weapon cannot be used. Its use would bring on the head of the offender, considered to be the mad dog of mankind, such a heavy retaliation (not necessarily nuclear), that its reminiscence would last for centuries. We must therefore limit ourselves to the hypothesis of the raving madman, which hounds to steal an atomic bomb. But these stories find their way better in Sean Connery's or Roger Moore's movies than in realness. Far from me the idea of making a mockery of non proliferation and diversion. I firmly believe, however, that the political world has undergone such a tremendous switch-over in the last few years, that the problem of nonproliferation and diversion of nuclear explosives shoud be studied anew, in connection also with the problem of the disposal od plutonium and of the secure storage both of plutonium and of HEU. The long storage time, in particular for HEU, which is such a begnin material, could be much more dangerous for diversion than the handling of plutonium to be used in nuclear fuels.

May I also add a few words about the possibility of ejecting the most toxic wastes into the sun. Prof. Theodore B. Taylor has suggested several tens of launches of a few tons at a time. I discussed a little with some of my collegues in the Energy Department of the Polytechinc school of Milano about the possibility of a multitude of launches (a kg each), so that a misfire would be an accident but not a disaster. Small unguided rocket-launchers, mass-produced, could be a solution specular to the giant launchers, using Saturn V-type boosters foreseen in the Taylor's hypothesis. It is to be remembered that Germany, at the end of World War Two, designed a facility for the production of 1 000 000 V-2 rockets per year; and it was not a joke, because in an artisan way and in a few months they built 10 000 such useless weapons plus 35 000 pilotless V-1 unguided missiles.

But we must turn back to our main purpose: to begin a preliminary discussion on the feasibility of dismantling the nuclear military capability existing in the world. As far as plutonium is concerned, military plutonium and civilian plutonium, although isotopically different, have common problems. And the utilization of plutonium mixes up with the problem af radwastes and disposal of fission products.

But high purity Pu-239 has a priceless value as a fuel for fast breeder reactors. The governements try to be still on the subject of breeders. And yet any of us knows that the fast breeder technology and that of the so called 'fusion reactors" are light-years apart. On breeder reactors (both fast and thermal), on whose technology we know a lot, we can say that they are 50 to 100 % more capital intensive than thermal light water reactors. But on the economy of "fusion reactors" we know absolutely nothing, much less than Fermi knew about thermal reactors on december 2, 1942.

This kind of silent hypocrisy would be very harmful to the discussions about the best processes to be used for dismantling the huge explosive potential of nuclear warheads existing in the world.

may, 1992 Mario Silvestri

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Nuclear Disarmament Process: A Global View

"Prospects of Nuclear Disarmament in a Changing World"

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Translation of advanced text

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Prospects of nuclear disarmament in a changing world

(Introduction: thanks to organizers)

"Prospects of nuclear disarmament in a changing world": this admittedly rather dry title of my talk could also be: How can we harness the huge nuclear potential for destruction which has been stockpiled in East and West, and elsewhere, over the past decades? Or, to put it another way: How can we force the genie back into the bottle from which it has escaped? This task has lost none of its significance in the wake of the upheaval of the last few years, although its nature has altered substantially.

Over the last two and a half years we have witnessed changes which have radically reshaped the political map of Europe. These changes made it possible for the East-West conflict to be overcome by peaceful means. The rejection of that bipolar world which determined our thoughts and actions for decades has fundamental repercussions for the international security structure, too. Yesterday's adversaries are today's partners. Who would have thought three or four years ago that representatives of the former Warsaw Pact and of the Atlantic Alliance would meet in the NATO Cooperation Council in a spirit of peaceful cooperation?

Today we have the opportunity to replace the arms race and mutual deterrents with cooperative security structures on both the global and regional level, to ease tensions, to harmonize conflicting interests by peaceful means, and to consolidate our common ground.

It is also true, however, that today's world is far from being idyllic. The radical transformation of the last years has brought to light new potential dangers which we must face up to: political and economic instability, social consequences of economic adjustment processes and the resulting massive migration, ethnic tensions and regional conflicts, but also the risks inherent in the proliferation of weapons of mass destruction.

In this situation it is inevitable that the role of disarmament and arms control be redefined. Arms control and disarmament played a vital part in overcoming East-West confrontation. We must face up to the new tasks ahead with this in mind.

On our continent, disarmament and arms control have hitherto been embedded in a Western security strategy in which a carefully graded nuclear arsenal afforded the final defence against attack. Disarmament was only possible within this framework of a "balance of deterrence". It concentrated on removing inequalities in holdings of the most dangerous and destabilizing weapons systems. In the nuclear field, the path led via the ABM Treaty and the START Treaty to the 1987 INF Treaty.

Clearly this philosophy must be subjected to a thorough review following the end of the East-West conflict. The threat pattern of the past - and thus also the need for strategic stability in the traditional form - is outmoded. Particularly in the nuclear sphere, however, there are legacies from the age of confrontation which must be dealt with as a matter of urgency. The problems posed by the nuclear weapons on the territory of the former Soviet Union are among them.

Disarmament and arms control under these new conditions will be guided by the following principles:

Firstly, there is agreement that a further reduction of existing weapons arsenals is sensible and possible. This applies in particular to the nuclear sphere, where prospects for further reductions have already been opened up by the unilateral announcements by President Bush and Presidents Gorbachev and Yeltsin. More than ever before, however, nuclear disarmament today is becoming a technical and financial problem.

Secondly, non-proliferation aspects are gaining in significance. They are, as we all know, inextricably linked with the process of further nuclear disarmament, as expressed in Article VI of the 1968 Non-Proliferation Treaty. This implies that disarmament is increasingly to be seen in global terms, as proliferation does not stop at national or continental boundaries. The strengthening of international non-proliferation regimes is therefore likely to become one of the most important instruments of peacekeeping in the coming years.

Thirdly, in arms control the traditional task of contractually regulating military potentials is becoming ever more closely tied to the political, economic, social and ecological aspects of security. Arms control will help to promote objectives such as demilitarization and conversion with a particular view to consolidating democratic developments. It will have to be taken into account in shaping a comprehensive, permanent dialogue on all these aspects. Its central task, however, will be to elaborate a cooperative strategy for conflict prevention to replace the current strategy of war prevention through deterrents.

Let me go into the first two points in more detail:

Worldwide the nuclear powers today have at their disposal tens of thousands of nuclear missiles. The explosive force of even the so-called tactical or battlefield weapons is in many cases much greater than that of the Hiroshima bomb. That such a huge destructive potential is no longer in line with requirements (and was, by the way, never actually needed for the purpose of mutual deterrence) is beyond doubt.

With the INF and START Treaties the United States and the former Soviet Union responded to the need to end the nuclear arms race, which was also economically disastrous. With the elimination of the intermediate-range missiles, a whole category of weapons disappeared for the first time in the history of disarmament. As regards the reduction in strategic nuclear strike weapons agreed in the START Treaty - which, we hope, will shortly be initiated following the readiness of Kazakhstan, Belarus and Ukraine to renounce these weapons after the expiration of the 7-year period agreed in the START Treaty - it turned out even when the Treaty was being signed that considerably more drastic cuts in arsenals could be undertaken without affecting security requirements. The unilateral disarmament initiatives of Presidents Bush and Gorbachev of last autumn, as well as the initiatives of the American and Russian Presidents of this January take account of this recognition. There is thus every indication that the tracks have been laid for further nuclear disarmament.

The realization of the measures and proposals envisaged by all these initiatives would lead to a further reduction of about fifty per cent in the strategic potential permitted under the START Treaty. And this does not even have to be the final word. At the same time the pressure would grow on other nuclear powers to stop withholding their nuclear weapons from the arms control process. The prospect of a world free of nuclear weapons, as envisaged by Article VI of the NPT, is again coming into view. Even if such an objective appears unattainable in the foreseeable future, we will do well to remind ourselves at least occasionally of this codified general target.

It was seriously envisaged as an ultimate aim immediately after the end of the Second World War, when Hiroshima and Nagasaki were still vivid, and before the political paralysis of the Cold War set in. It found concrete expression in the draft to the so-called Acheson-Lilienthal-Baruch plan of 1946, which was designed to subject the total potential of available nuclear weapons to a reliable international control regime with a view to its gradual elimination. The Baruch plan contains projections which are still topical today: it proceeds on the basis of a worldwide approach, and from the need for as much transparency and verifiability as possible, and is based on the view that questions of nuclear disarmament affect the security interests of the international community as a whole.

Allow me to add a few words on one particular aspect of the American and Soviet undertakings of autumn 1991: namely, the undertaking to renounce in future all land-based short-range nuclear missiles, artillery munition and nuclear mines. Following the elimination of intermediate-range missiles, this would do away with a second weapons category, involving particularly high security risks, which in the Europe of the 90s no longer serves any purpose. The decision to eliminate this category is in keeping with a long-standing concern of the Federal Government. Foreign Minister Genscher last drew attention to this in a public statement at the beginning of this year in which he called for the worldwide elimination of all land-based short-range nuclear missiles and nuclear artillery munition in the CIS states and in the USA. The elimination of these missiles is, however, by no means exclusively a German concern. Just imagine the havoc these short-range nuclear missiles would cause in the regional conflicts currently taking place in Europe following the end of East-West confrontation. It is obvious that any such deployment must be prevented. The complete elimination of this category of weapon affords the best guarantee of this.

One thing is already certain: the task for the coming years will be to achieve the contractually agreed or announced elimination of thousands of nuclear warheads. We have no experience so far which would prove the practicability of this task. It is already evident that it will require a substantial financial commitment.

The most pertinent example in this connection is the nuclear weapons on the territory of the former Soviet Union. These weapons largely lost their security function with the end of East-West confrontation. I do not need to go into the details here, which will be the subject of further discussions at this symposium. Suffice it to say that we are talking about a total of roughly thirty thousand nuclear warheads, the majority of which - pursuant to contractual arrangements or undertakings given by Presidents Gorbachev and Yeltsin - are to be eliminated in the next few years. This figure includes about twenty thousand tactical warheads which, owing to their easy handling and high mobility, pose a particularly serious security and proliferation risk.

It goes without saying that this creates for disarmament new problems of previously unknown dimensions. The security of the entire international community is at stake. The aim must be resolutely to seize the present opportunity to destroy as many nuclear weapons as possible. This gives rise to unfamiliar questions: for instance, what is to happen to the weapons-grade fissionable material (i.e. plutonium and highly enriched uranium) that is released from the warheads? After all, we can expect approximately 120 tonnes of arms-grade plutonium and 700 tonnes of highly enriched uranium to be released from these weapons. Present processing methods are costly and not fully matured. This opens up new prospects for supranational cooperation on security. As many parties as possible should participate - the obvious precondition being strict adherence to the commitments under the Non-Proliferation Treaty.

This brings me to the second aspect: the growing importance of the issue of non-proliferation. Nuclear disarmament and non-proliferation are inseparably linked. The elimination of weapons of mass destruction would undoubtedly be the most efficient way to prevent their proliferation. But this is a political issue and politics, as we all know, does not always follow the laws of Cartesian logic. In the case of biological weapons, the target has largely been achieved, and the outlook for a global ban on chemical weapons is not bad. However, the situation with nuclear weapons is more complicated. Existing nuclear powers will not renounce these weapons completely as long as they consider themselves to be threatened by weapons of mass destruction. This should not, however, deter us from resolutely continuing our efforts towards disarmament in that sphere as well.

At the same time the increasing proliferation of weapons of mass destruction must be resolutely stopped. At present more than twenty countries have nuclear, biological or chemical weapons or their delivery systems at their disposal or are in a position to develop them. The example of Iraq ought to have a deterrent effect. It shows how the possession of weapons of mass destruction can trigger aggression and aggravate regional conflicts with far-reaching implications.

There are many different reasons for the increasing proliferation of weapons of mass destruction: first, it is easier now than it used to be to procure the appropriate technologies on the world market, especially as they are mostly dual-use technologies for both military and civilian purposes. Second, pride and the need for security provoke the neighbours of countries which possess weapons of mass destruction into acquiring comparable capacities for themselves. And there are enough unscrupulous dealers, companies and even states which, either from greed for profit or ideological blindness, facilitate the proliferation of these weapons.

Finally, with the collapse of the political and economic structures in the former Soviet nuclear power, and as a result of the economic problems of its successor states, a new, hitherto insignificant aspect of the proliferation risk has come to the fore; human know-how about the development and manufacture of weapons of mass destruction, a hazard with worldwide implications in our specific situation, the question is how can a former Soviet arms scientist or engineer threatened with unemployment be prevented from taking up work as a technology mercenary with an aspiring nuclear power.

Of course there is no overall solution to the non-proliferation issue. It is true, however, that awareness of the inherent dangers is growing within the international community, as is the willingness to cooperate in overcoming them. This is reflected both in the voluntary undertaking by the currently eighteen states in the MTCR to also prevent the proliferation of delivery technology and in the common export control on nuclear dual-use products, and on chemical and biological precursors within the so-called Australia Group.

The recent accession to the Non-Proliferation Treaty by the People's Republic of China, a similar announcement by France and the willingness of Ukraine, Belarus and Kazakhstan to accede as non-nuclear countries are further encouraging signals in this connection. The Non-Proliferation Treaty, on whose unlimited extension a decision will be taken in 1995, is the only global instrument for the prevention of nuclear proliferation. Despite its shortcomings, it is indispensable. All measures to consolidate its validity deserve our support.

However, the existing non-proliferation regime is targeted only at countries without reference to action taken by individuals on their own responsibility. This, therefore, was the subject of the initiative which the German Foreign Minister submitted to the UN Secretary-General in January in the form of three proposals: firstly, the creation of incentives within the framework of an international foundation for arms experts to use their skills for peaceful purposes in their own country; secondly, the call on UN member states to subject their nationals who participate in the development and manufacture of weapons of mass destruction, whether at home or abroad, to domestic criminal proceedings; and thirdly, a call on the UN Security Council to view breaches of the NPT as a threat to international peace and security and to impose sanctions against those countries which violate international law by procuring know-how and potentials for the production of weapons of mass destruction.

The first proposal took on concrete form within six months with the establishment of the International Science and Technology Centre in Moscow which is sponsored by Russia, Japan, the United States and the EC. Our Foreign Minister's other proposals, too, met with broad approval; they point the way forward for the debate about specific measures to be taken at international level to promote non-proliferation.

In implementing these measures, it will always be imperative to proceed from as broad a basis as possible. I have already mentioned the need for non-proliferation to be consistently backed up by disarmament measures within the meaning of Article VI of the NPT. Other factors, too, must be taken into account. For example, non-proliferation measures will also have to consider the legitimate requirements of economic development. From the point of view of the Third World countries in particular, it will be important to retain or expand the technical framework for peaceful domestic development. The question as to how the transfer of technology for peaceful purposes can be reconciled with the need effectively to stop the proliferation of weapons of mass destruction or their precursors is an unavoidable one and indeed the hinge linking non-proliferation policy and international economic and scientific cooperation. Current non-proliferation policy necessitates, furthermore, the provision of assistance in the conversion of military potentials.

This brings me back to where I started. The further course of nuclear disarmament - I hope to have made this clear - remains firmly embedded in a larger political framework with increasingly global implications. But the degree of international stability in the coming years obviously also depends on the determination to proceed further along the road to nuclear disarmament. If we can seize the new opportunities in a cooperative spirit, the outlook is not that bad.

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Nuclear Disarmament Process: A Global View

"Conversion of Nuclear Complex of the Russian Federation and Nuclear Disarmament"

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Report of the Minister of the Russian Federation for Atomic Energy at the international simposium in Rome, 15-17, June, 1992.

Nuclear weaponry complex conversion and nuclear disarmament in the Russian Federation.

Russian atomic energy was being created during the hard years of World War II and right after it, following the information of theGerman physicist-communist C.Fuchs on wide U.S. nuclear armes researches. The USSR government authorized I.V.Kurchatov to head the first atomic science centre and to run all the researches in the nuclear area.

The interdepartmental governmental body-The First Main Department under the USSR Council of Ministers, was established on August,29,1945 with the authority to coordinate all the activities in the field of nuclear science and technology.

Sumultaniously large nuclear scientific centers & nuclear industry were being developed. Such a comprehensive approach provided for the possibility of developing within a short time period a number of new scientific & technical branches in the nuclear area including such, as: uranium ores mining & processing technologies, nuclear material testing & metallurgy, radiochemistry, nuclear engineering & instrumentation industry, radiation techniques, dosimetry & protection, high temperatures & pressures physics, high energy physics & quant electronics, etc.. At the same time serious matters, related to envioronment & personnel health protection, as well as wastes disposal had to be dealt with.

Together with the nuolear industry establishment a oorresponding system of teohnioal codes & regulations was developed for the the whole of nuolear-dangerous produotion process, starting
with uranium mining down to the final produot manufaoture, inoluding utilization & supervision.

The Ministry of Medium Mashinery of the USSR was established in 1953 for administrative oontrol over the new branoh,it was reorganized into the Ministry of Atomio Power & Industry (MAPI) in 1989.

The Ministry for Atomio Energy of Russian Federation was established on the 28 of January, 1992, by Number 61 president Yeltsin's deoree. It is a legal suooessor to the liquidated MAPI on issues under the jurisdiotion of the Russian Federation.

MinAtom is resposible for:

providing nuolear and radioaotive safety for the nuolear oomplex, radioaotive wastes handling and enviromental rehabilitation of theareas;

organization and exeoution of state supervision over the nuolear oomplex aotivities and oonseoutive conversion;

pursuing state soientifio and teohnioal, investitional and struotural polioy in the field of atomio power industry development;

elaboration & exeoution of programs in the field of nuolear weapons taking into aooount the reduotion of Russian nuolear arsenals.

For pursuing a similar soientifio and teohnioal polioy two soientifio and teohnioal ooordination oounoils in the fields of general nuolear soienoe and teohnology and nuolear weapons were established at the Ministry. The oounoils and their seotions inolude both soientists of the Russian Aoademy of Soienoes and leading
soientists of the branoh.

The branoh is the olosed soientifio and industrial oomplex of teohnologioally linked plants for raw materials extraotion, fissile materials produotion, manufaoture of produots for the needs of nuclear power generation & nuclear weapons industries, spent fuel

reprocession with a subsequent localization & disposal of wastes, as well as a number of support & supply enterprises. An emergency fast action system in cases of nuclear accidents in transportation & production has also been organized.

The overall cost of the basic industrial assets, belonging to 151 of MinAtom enterprises with an over 1 million personnel is around 35 billion USD. 47,2% of the entire personnel is engaged in the manufacture process, 16,5% - in science, 19,4% - in construction & 16,9% in other nuclear related branches. At present a number of concerns & industrial assosiations has been established within the framework of the Ministry, majoring in various areas of conversion.Their activities are planned to be further broadened in the directions most adaptable to commercial structures. When preserving a hieralchical management structure in the nuclear branch & at the same time flexibly coordinating activities on the horizontal levelit is most important to keep the optimum balance which appropriatly reacts to the constant changes in the russian market being also attractive to the foreign investors.

The overall industrial output of Minatom in 1991 was around 20 billion USD, including 2,9 billion for arms & military techniques & 8 billion USD for special nuclear materials.

The trading activities of the Ministry in the foreign markets have significantly increased over the recent years, which provided for a 500 million USD products export in 1991. Within the structure of Minatom's export prevail(90%) those products, that are in abundance for internal use in the Russian Federatin, i.e. natural & enriched uranium, fuel & equipment for Nuclear Power Plants, rare-earth elements. Of all the enterprises of the former USSR MAPI, 80% out of all enterprises of the former USSR MAPI are located in Russia, 7% - in Ukraine, 4% - in Kazakhstan, 3% - in Uzbekistan, 2% - in Estonia, and 5% - in other Republics.

One of the Minatom priority tasks consists in preservation and development of technological and scientific-technical relations with the CIS and East-European countries.

The following subbranches may be distiguished within the frames of the Russia Minatom:

1. The nuclear weapons potential of the Minatom represents a unique national complex of R&D institutions, design offices and serial production plants. The enterprises of this complex are conducting fundamental and applied research, R&D activities, in-field weapon prototype tests at the national nuclear test sites, serial production and supervision.

The complex includes ten cities closed due to the dangerous production conditions and security regime with total population of 0.7 million people. Hereto refer the Russian federal nuclear centres - the All-Russian R&D Institute of Experimental Physics (Arzamas-16) and the All-Russian R&D Institute of Technical Physics (Chelyabinsk-70).

Nuclear weapons development and production are concentrated exclusively within the territory of the Russian

Federation.

The priority direction of activities in this area consists in increasing nuclear weapon safety, reliability and efficiency on the basis of the complex scientific potential preservation.

The industry mentioned above represents the only national institution in the field of nuclear weapons production over the entire technological cycle with supervision in the Joint Armed Forces on the basis of the unified scientific-technical policy, providing also for nuclear weapons production and maintenance, based on the standardized technical documentation and technical supply base.

One of the most important current aspects of the Russia Minatom activities refers to utilization of nuclear ammunition with the expired terms of storage in accordance with the nuclear weapons reduction programme. The amount of these activities at present significantly (more than two times) exceeds the amount of serial nuclear weapons production.

Nuclear disarmament started practically right after the MSRM Treaty entered into force in 1988.

The nuclear arsenal decreased presently by approximately 20%, taking into account all the treaties related to the nuclear weapons reduction.

2. The power engineering subbranch of the Russia Minatom includes nine operating nuclear power plants (28 units) with a total capacity of more than 20 GW.

R&D enterprises of the Minatom are carrying out fundamental research in nuclear fission physics, developing the scientific basis for nuclear power engineering, designing nuclear reactors and power facilities for military and civilian application. A large-scale volume of activities is conducted at the Physical and Power Institute in Obninsk, R&D Institute for Atomic Reactors in Dimitrovgrad, All-Russian Research Institute of Inorganic Materials after A.A.Bochvar, R&D Institute for Power Engineering Technique in Moscow and in large design offices and scientific groups in St.Petersburg and Nizhny Novgorod.

3. The industry is characterized by its leading role in the field of machine and instrument building, which constitute its technical basis.

The industrial enterprises develop and produce multipurpose detectors of ionizing radiation, radiation monitoring and transient process detection systems, radioelectronic devices, semiconducting laser emitters and apparatus for scientific investigations. Substantial experience is accumulated in the sphere of development and production of chemically and radiation resistant equipment for nuclear industry, aimed at long-term and reliable operation under extreme conditions.

4. Traditional fundamental research remains to be the scientific basis for R&D activities of the industry in the

field of nuclear physics and high-energy physics, thermonuclear fusion and high-power laser radiation, accelerator technique and superconductivity.

The industry's R&D institutions of fundamental profile are characterized by the availability of unique research complexes, including the largest in the world accelerating storage ring with a capacity of 3000 GeV now under construction in Protvino, Moscow region, at the High Energy Physics Institute and located in the circular underground tunnel, 3.5 m in diameter and 21 km long (the first stage start-up in 1995). The Institute for Theoretical and Experimental Physics and the V.G.Khlopin Radium Institute are also greatly contributing to science.

5. International Cooperation.

Scientists of the nuclear industry are actively participating in the international organizations - the CERN and the Joint Institute of Nuclear Research in Dubna.

Through the IAEA the Ministry supports participation of the Russia in international activities related to non-proliferation of nuclear weapons, control over the use of nuclear energy for peaceful purposes, nuclear export control.

The Ministry ensures the realization of nuclear test control in the USA in accordance with the Threshold Treaty, 1974, ratified in 1990.

Altogether, the Russia Minatom participates in the implementation of over 20 intergovernmental and nearly 30 intersectional agreements with foreign countries in the field of the use of nuclear power.

One of the main tasks facing the Russia Minatom is broadening and deepening of international scientific and technical contacts, especially on the basis of joint works dealing with the safety improvement of the nuclear power industry and the conversion of military production, as well as the establishment of an international conversion centre for the benefit of the Russian industry.

6. The Russia Minatom has a powerful construction industry with 3 billion roubles a year of construction and installation works, where a great experience has been accumulated while building complicated and unique nuclear power facilities and the whole range of works is fulfilled from designing of projects to their construction and "turnkey" equipment installation both in the territory of the CIS and abroad.

The ministry's specialized enterprises undertake installation and reconstruction of nuclear reactors, thermal power plants, nuclear particle accelerators, technological pipelines, chemical technologies and capacities, mining structures, complex construction of towns and settlements (e.g. Shevchenko built in Kazakhstan, Navoi in Uzbekistan, Obninsk, Dubna and other towns) of the nuclearpower industry of the CIS.

CONVERSION IN RUSSIA MINATOM

The profound political and economical reform carried out in the CIS, the doctrine of ensuring sufficient defense of the Commonwealth, as well as the necessity of ecological revival of the territories and safety improvement of the population, have demanded to conduct conversion of the scientific and industrial potential of the nuclear power industry as a result of both the reduction of weapons and military production and radical cut-back in designing and construction of new nuclear power plants, including the decommissioning of some operating power units and substantial decrease of uranium mining and reprocessing volumes.

Taking into account the existing conditions, complex research works for selecting economically effective tasks of the conversion directions of the nuclear industry's activities, which are the most adequate to the accumulated scientific, industrial and staff potential were carried out in 1988-1990 using all the established economic ties on the basis of the developed nuclear power industry. The assigned aims and tasks of the Russia Minatom development in 1991-1995 and up to 2000 have formed the basis for elaborating a number of goal-oriented comprehensive national programmes on development and fabrication of technology-intensive civilian products. The goal-oriented programmes are focused on the priority development of technologies of two-purpose application on the basis of the key advanced technologies. The development and rate of conversion return to the national economy will be strongly depend on the credit and financial and tax policies of the state on its way to the market.

While developing all the conversion programmes the Ministry paid the main attention to the task of increasing tproduction of consumer goods in 1990-1995 (3.6 times). In 1990 the output of consumer goods accounted for 390 million roubles, in 1991 it accounted for 766.3 million roubles. Production of science-intensive goods and those of short supply is taken into account.

The conversion programme can be successfully implemented only if the nuclear industry is functioning as a unified scientific and industrial complex, since a wide range of interrelated works has to be conducted by a great number of specialized research institutes, design offices, industrial enterprises and costruction organizations functioning within different central boards and concerns of the Russia Minatom. The preservation of stable technical and production, as well as scientific ties within the Commonwealth of Independent States.

The gross conversion industrial output in 1991 was 2.8 billion roubles, and the 4.3-fold increase is planned by 1995.

Today it is very important not to loose the achieved rates of conversion.

One of the most significant tasks of the Minatom consists in activity coordination and constant safety improvement of previously constructed nuclear facilities, in implementation of measures related to their decommissioning and upgrading of the ecological state of the contaminated areas in different regions of the country.

The programme for ecological environmental restoration of the above-mentioned territories and radioactive waste management are the constituent and priority parts of the military production conversion.

In accoradance with the Decree issued by the President of the Russian Federation on creation of the Minatom of Russia, the list of legislative and other regulatory documents related to the safety of nuclear power utilization, the development and adoption of which on the legislation level shall provide for safe nuclear complex functioning, has been prepared and sent to the Government.

Under the conditions of formation of the Commonwealth of Independent States the Russian Federation retains within the frames of the Russian Minatom the well-established nuclear power complex; constituting technologically inseparable scientific and production structure with predominance of interrelated reallotments, dangerous from the nuclear and radiation point of view, well-developed scientific and experimental basis, construction industry and social infrastructure, continuous personnel training system and special medical service.

This is the necessity to provide for safe functioning of nuclear power facilities and accomplishing the measures for environmental protection and restoration, methodical conversion and executionn of international obligations in the corresponding fields of science and technology, including the control over nuclear tests and nuclear weapons reduction.

The draft agreement between the member-states of the Commonwealth of Independent States on cooperation in the field of peaceful use of nuclear power is prepared to provide for advantages of interstate cooperation, taking account of more than fourty-year functioning of the unified nuclear complex in the former USSR.

Minister for Atomic Energy
of the Russian Federation
professor V.N.Mikhailov

June, 1992

FONDAZIONE PER LA PACE
E LA COOPERAZIONE
INTERNAZIONALE
"ALCIDE DE GASPERI"

S T E S
SCIENZIATI E TECNOLOGI
PER L'ETICA DELLO SVILUPPO

4

International Symposium

on

"CONVERSION OF NUCLEAR WARHEADS FOR PEACEFUL PURPOSES"

Palazzo Doria - Rome
June 15-17, 1992

Nuclear Disarmament Process: A Global View

"Ethical Values, Disarmament and Development"

by J. JOBLIN

Secretariat:
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SCIENTIFIQUES ET TECHNICIENS POUR L'ETHIQUE DU DESARMEMENT

VALEURS ETHIQUES, DESARMEMENT ET DEVELOPPEMENT

Joseph Joblin sj
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Tout individu est aujourd'hui au centre d'une contradiction. D'une part, il voudrait participer a la solution des problemes qui le conernent; mais d'autre part, il a l'impression de n'avoir aucune prise sur leur solution. Celle-ci dépend de décisions prises au niveau mondial et devant lesquelles il se sent impuissant. Les grandes options en matiere de protection de l'environnement, de lutte contre la maladie, de modèle social plus ou mons dirigiste, pour ne prendre que quelques exemples, sont prises sans qu'il ait la possibilite d'exprimer un avis reflechi. D'ailleurs comment le pourrait-il, puisque les données de chacun de ces dossiers lui echappent.

Le sentiment de l'homme moderne d'être incapable d'agir sur les orientations ethiques de la société ou il se trouve se vérifie pour les questions de desarmement. Chacun condamne, en ce qui le regarde, la course aux armements, specialement nucléaires, car il y voit une "absurdité" (Jean-Paul II); tout le monde est pr^et a souscrire au memorandum que la Commission Pontificale Justice et Paix adressa au Sécrétaire général des Nations Unies en décembre 1975 où déclarait que la course aux armements était un "danger" puisque les stocks d'armes nucléaires étaient tels qu'ils pouvaient détruire la planète, une "injustice" puisqu'elle renverse l'échelle des valeurs en consacrant le primat dela force, un "vol" des biens qu'elle mobilise alors que tant de pauvres en auraient l'us pour devenir plus homme, une "erreur" dans la mesure où on la tient pour nécessaire afin de donner du travail aux hommes alors qu' l'on pourrait reconvertir progressivement les usines d'armements; et Paul VI ajoutait une "faute" contre la vie en travaillant pour la mort et, finalement une "folie" puisque, censée protéger l'humanité, elle la conduit à la ruine.

Ainsi donc le problème moral devant lequel se trouve l'homme contemporain peut être formulé en ces termes:

1) l'état des relations internationales l'oblige à s'armer pour ne pas laisser la route libre aux "criminels sans conscience" et aux "malfaiteurs internationaux" (Pie XII 3 octobre 1953)

2) mais le recours aux armements pour garantir la paix s'avère un jeu dangereux et stupide

3) une relative détente internationale offre une chance à nostre époque; la fin de la méfiance institutionnalisée entre les blocs ouvre un défi pour les nations industrielles les plus expertes en matière d'armements de réorienter leurs ressources vers la paix

4) dans cette situation, quelle est la responsabilité de chacun, en tant que citoyen, militaire, industriel ou gouvernant pour hater cette reconversion des industries de guerre vers des productions de paix? Problème extrêmement vaste sur lequel il s'agit de jeter ici quelques coups de projecteur du point de vue éthique. Il s'agit d'illustrer simplement cette proposition: tout homme désireux de se comporter d'une manière responsable dans les questions liées à celles du désarmement et de la reconversion industrielle doit relever un triple défi en envisageant ses obligations sous trois angles global, personnel et progressif; ce sont ces trois termes que je voudrais commenter ici brièvement.

1. <u>Le défi éthique aujourd'hui: une contrainte globale</u>

La morale n'a jamais été purement subjective; comme si l'individu n'était lié par aucune obligation tenant à sa condition humaine vis à vis des autres membres de la société. La moralité etait présentée comme l'acceptation (ou le refus) d'un ordre objectif. Elle insiste donc sur la disponibilité de l'homme à obéer ou non à cet ve...

L'Europe a vécu sur cette conception jusqu'à la deuxième guerre mondiale; c'est alors que progressivement une nouvelle conception de la moralité a commencé à s'imposer, celle d'une contrainte globale.

Il est facile de comprendre quelle fut la transformation à laquelle il est fait ici allusion si l'on se souvient de la manière dont leurs obligations morales vis à vis de la societé étaient présentées aux individus à l'époque féodale et plus tard au temps des nationalismes. Dans l'un et l'autre cas, l'ordre social était une valeur objective fixée une fois pour toute ici la chretienté, là la nation, qui méritait que l'individu se sacrifiat à elle; le prince, puis les hommes de gouvernement, interprétaient quels étaient les intérets supérieurs auxquels l'individu devait se soumettre s'il ne voulait pas etre taxé de "chevalier félon" ou de "traitre à la patrie".

Le parallélisme qui vient d'etre évoqué n'est pas total. Alors que la chrétienté constituait théoriquement un tout organique dans lequel venait prendre place chaque entité politique inférieure, la societé internationale qui se créa aux 19 et 20émes siècles fut égalitaire, interétatique. Alors que la première fut confessionnelle, la seconde fut laique. Les Etats sont ici les sujets de l'ordre international; souverains, ils ne renoncent à leur droit de faire la guerre que dans les limites qu'ils ont souscrites. Ces principes qui étaient à la base de la Société des Nations qui regroupait des individus-Etats se disloqua dès que l'un d'eux avait des intérets propres.

A partir de 1945 se développa une nouvelle perception de la paix. D'une part, la société internationale n'est plus celle que forment les Etats mais les peuples, comme le proclament les premiers mots de la Charte des Nations Unies; ce sont eux qui mandent leurs gouvernants pour construire la paix et le nouvel ordre mondial. D'autre part, et surtou, la paix n'est plus conçue comme une simple absence de guerre mais comme une "construction" (Gaudium et Spes, le "resultat d'une action morale et juridique" (Pie XII, Message de Noel 1943).

Morale, c'est à dire que les problèmes qui posent aujourd'hui aux hommes sont perçus etre tels qu'ils ne peuvent etre résolus que par des mesures arretées à l'échelle mondiale et que les peuples se sentent responsables d'entrer dans cette voie. Le président Roosevelt est un des tout premiers hommes d'Etat qui a fait prendre conscience de cette nouvelle dimension de la moralité lorsqu'il a prononcé son discours dit des quatre libertés (26 janvier 1941) demandant qu'à l'issue de la guerre soit instauré un monde où soient assurées la liberté d'opinion et d'expression, la liberté de religion, la libération de la faim, et celle de la crainte et de la peur.

Juridique. Quelques années plus tard, l'Organisation internationale du travail redéfinissant ses finalités avant d'aborder la reconstruction de l'après-guerre adoptait à Philadelphie, en 1944, la Déclaration dite de Philadelphie qui faisait entrer cette philosophie dans le domaine de l'action internationale institutionalesée; les délégués du monde libre y proclamaient:

la lutte contre le besoin doit menée avec une inlassable énergie...
la réalisation des conditions permettant d'aboutir à ce résultat doit constituer le but central de toute politique nationale et internationale ..
convaincue qu'une utilisation plus complète et plus large des ressources productives du monde, nécessaire à l'accomplissement des objectifs énumérés dans la présente Déclaration peut etre assurée par une action efficace sur le plan international et national ... la Conférence promet l'entière de l'Organisation internationale du travail avec tous les organismes internationaux auxquels pourra etre confiée une part de responsabilité dans cette grande tache ...

Telle est donc la nouvelle situation devant laquelle on se trouve: alors que jusq'au 19éme siècle, et meme jusqu'en 1940, la formation morale se désinteresait largement de l'organisation et de son devenir, il n'en va plus de meme depuis la fin de la dernière guerre mondiale. De meme que "la pauvreté où qu'elle existe est un danger pour la prospérité de tous" (Déclaration de Philadelphie), l'éradication de la pauvreté devient désormais du domaine de la responsabilité de chacun d'entre nous.

Ce changement d'attitude a une incidence sur les questions de désarmement. Alors qu'autrefois les politiques d'armement relevaient de la seule compétence des Etats et que les peuples n'y avaient point part, aujourd'hui la part des budgets consacrés à l'armement par les Etats particuliers se trouve soustraite aux sommes que la communaute internationale peut et doit consacrer au développement de chacun et de tous. La paix est devenue le fuit d'une stratégie globale assumée par tous.

2. Le défi éthique aujourd'hui: une contrainte personnelle

Pendant des siècles les habitants des deivers pays ont été étrangers à la conclusion de la paix ou au déclanchement des guerres; ils subissaient ce que les princes avaient choisi. Les prières que les peuples adressaient au Ciel reflétaient cette impuissance; ils attendaient de la divinité qu'elle se comporte comme un Seigneur de la guerre plus puissant que les autres en imposant sa paix.

L'apparition des régimes démocratiques a changé cette perception que l'homme avait par rapport à la paix et à la guerre; elle a donné lieu à la formation des Mouvements de la Paix. Sans doute y eut-il toujours dans les pays de chrétienté, des hommes qui voulurent prendre l'Evangile dans toute sa rigueur logique et dénier tout caractère de légitimité à la violence; mais ils furent marginaux; ils n'eurent pas d'influence sur la marche de la société d'autant que la plupat d'entre eux vécurent en marge de celle-ci. Il n'en alla plus de meme avec la Quakers.

William Penn (1644-1718) fut, au nom du quakerisme, fodateur d'un Etat pacifiste la Pensylvanie. Le fait qu'il exista durant près d'un siècle montra que l'on pouvait tenter de réaliser poliquement une société pacifiste. Dès de début du 19éme siècle, les premières sociétés de paix apparurent, simultanément, à l'initiative de membres des Quakers, tant aux Etats-Unis qu'en Grande Bretagne; elles furent le premier germe qui a conduit aux grandes manifestations en faveur de la paix des années 80. L'on se trouve ici devant un mouvement de fond qui a une signification qu'il faut comprendre et accepter, en dépit de toutes les ambiguités qui l'ont entouré durant ces derniers années. Il est une manifestation de la volonté des peuples de jouer une part active dans la détermination de la politique des gouvernements afin de l'orienter vers la paix. Ici encore nous trouvons devant un noveau défi éthique; celui concerne le comportement journalier de chacun.

Plus un régime assure la participation libre des citoyens aux affaires publiques, plus ceux-ci sont responsables de construire la paix dans et par leurs activités journalières. Autrefois, l'on estimait que les décisions dès gouvernements représentaient vraisemblablement le meilleur choix pour la sauvegarde de l'intéret général; aussi chacun était-il tenu de lui obéir et l'objection de conscience trouvait difficilement sa place dans les traités de morale. Aujourd'hui, la remise l'honneur de l'objection de conscience est la conséquence de la nouvelle perception que l'on a de la responsabilité de l'homme vis à vis de la société. Une intervention de Jean-Paul II à Spire met bien en évidence le rapport que l'on saisit aujourd'hui entre l'action quotidienne de l'homme engagé dans la vie courante et la politique globale:

Peut-etre serez vous nombreux à penser en cet instant: ... la paix mondiale ... est bien parmi - les défits cruciaux de notre temps; mais que ouis-je faire, moi, tout seul? Est-ce que je peux vraiment apporter ma contribution? A cette question, jre vous apporte la réponse. Qui toi, individuellement, tu peux amorcer le mouvement; car, toute bonne résolution, toute prise en charge volontaire d'une tache ne se décident jamais que par un individu. Et meme sil est nécessaire que les efforts de chacun soient ensuite reliés a ceux d'autrui pour obtenir de grands effects il n'en reste pas moins que le "oui" de chaque personnee, formulé avec générosité et fidèlement maintenu, dans sa sphère d'activités, est indispensable pour amorcer et promouvoir efficacement ces améliorations profondes au niveau de l'Eglise et de la société. Homelie devant la cathédrale de Spire 4 mai 1987 in Documentation Catholique 1987 590 (Osservatore Romano 6 mai 1987).

Ainsi, c'est donc parce qu'aujourd'hui de grands effets ne pouvent etre obtenus sans que les efforts de chacun ne soient reliés à ceux d'autrui qu'une responsabilité personnelle incombe à chaque citoyen vis à vis de la politique de son gouvernement; et c'est parce que ces grands projets sont aujourd'hui mondiaux qu'une opinion mondiale doit se constituer présentement en faveur du désarmement; mais une opinion mondiale responsable.

L'ensemble des pays industrialisés a été traversé au cours des dix dernières années par les courants suscités par les mouvements de la paix qui prétendaient influencer les décisions des gouvernements. Leur action a constitué un apport positif à la cause de la paix et du désarmement du fait que l'écho qu'ils ont recontré dans l'opinion mondiale a montré combien ce thème lui était proche et a été l'occasion, pour beaucoup, d'un éveil à l'idéal de paix (J.Joblin, L'evoluzione storica dei movimenti per la pace in Civiltà Cattolica A1984 II 536-549; d°, I problemi dei movimenti della pace oggi, ibidem 1984 IV 334-346; d° L'avenir des Mouvements de la Paix in Actes du symposium sur les "Mouvements de la Paix" organisé conjointement par la Fédération Internationale des Universités Catholiques et la Club de Rome, Salzburg 18-21 février 1983 Centre de la Recherche de la F.I.U.C. 1984 pp.8-22; d°, Problématique des Mouvements de la Paix Ibid. pp.325-331). Mais cette acion sur l'opinion publique est condamnée à rester assez superficielle aussi long temps qu'elle n'entraine pas dans son sillage les responsables des politiques d'arment tant au point de vue politique qu'industriel. Leur resposabilité est délicate puisqu'ils ont à la fois à retenir leur pays sur la voie de la course aux armements comme à chercher à associer à cette politique, d'une manière les décideurs réaliste des autres pays; mais également, ils sont redevables devant leurs concitoyens de leur sécurité. Si nous prenons le cas des industries d'armements, il se trouve qu'elles font objectivement hobstacle à la paix puisq'elles détournent une partie des ressources mondiales de taches qui pourraient favoirser positivement le "progrès matériel et développement spirituel" de l'humanité. Chacun doit donc s'interroger sur la mesure dans laquelle il contribue à créer ou entretenir une psychose de méfiance entre les peuples au-delà de ce qui est requis par la sécurité de son propre pays. Autrement un sentiment nationaliste faisait devoir de soutenir aveugement la politique militaire de "son" gouvernement; aujourd'hui, un sentiment internationaliste demande d'"examiner ... tous les programmes d'action et mesures d'ordre économique et financier" et de les "considérer à la lumière de cet objectif fondamental" (Declaration de Philadelphie) qu'est l'elimination de la pauvreté et la véritable promotion humaine de tous et de chacun (Populorum Progressio). De nouveaux paramètres doivent donc entrer dans les jugements moraux des hommes politiques, des industriels et des simples citoyens.

3. Le défi éthique: concrétiser l'impératif de paix

La responsabilité que l'on met sur les épaules des individus peut sembler bien lourde; car s'il est aisé de tomber d'acord sur la nécessité de donner une orientation morale aux activités économiques, les raisons sont multiples pour ne s'engager que prudemment sur cette voie (J.Joblin, I cristiani e le industrie che producono armi in Civiltà Cattolica 1991 II pp.316-329). L'économie actuelle est soumise à la loi de la concurrence de meme que les relations inter-étatiques sont marquées par la méfiance et la soif de dominer. Celui qui n'accepterait pas de ejover ce jeu se designerait en effet pour devenir le grand perdant de la partie qui est engagée. Le monde est soumis à la loi du plus fort et malheur à celui qui entend s'y soustraire.

Des signes existent cependant que la loi du plus fort n'est pas la seule qui règle les relations entre les acteurs de la politique mondiale. Ceux-ci obéissent aussi à des considérations morales et, les choses étant ce qu'elles sont, il s'agit d'en élargir le champ. Il s'agit de s'engager dans un processus qui opere une mobilisation de l'opinion, non seulement celle de la masse inorganisée, mais aussi des professionnels de la politique et du monde des affaires pour faire entrer la contrainte globale du développement pour tous dans les décisions des responsables de l'économie et de la politique; leur détermination trouvant un soutien dans l'attitude de l'opinion publique.

Cette nouvelle moralité s'appuiera sur deux évidences qu'il s'agit de vivre soi-meme afin de les faire partager autour de soi: les populations marginales doivent etre réintégrées dans le concert des peuples; cette réintégration doit commencer par les plus pauvres. Précisons ces deux impératifs pour montrer qu'il ne s'agit pas de paroles en l'air.

* la réintégration des populations marginales dans le concert des peuples comporte un double aspect, l'un négatif, l'autre positif. Négativement, cela signifie que

l'on doit juger intolérable l'existence de telles groupes d'hommes de la meme manière que l'on juge intolérable la présence de mendiants à la porte des palaces; mais au lieu d'appeler la police pour les chasser, il faut prendre sur soi-meme et se demander comment, moi, je puis aider, voire m'investir pour les faire sortir de cet état d'exclusion qui est le leur. Il faut prendre à la lettre cette déclaration du Concile Vatican II:

Les peuples de la faim interpellent les peuples de l'opulence Gaudium et Spes §9,1
Le luxe cotoie la misère. Tansis qu'un petit nombre d'hommes disposent d'un très ample pouvoir de décision, beacoup sont privés de presque toute possibilité d'initiative personnelle et de resposabilité; souvent ils sont placés dans des conditions de vie et de travail indignes de la personne humaine d° §63,3
Tandis qu'on dépense des richesses fabuleuses dans la préparation d'armes toujours nouvelles, il devient impossible de porter suffisamment remède à tant de misères présentes de l'univers ... Il faudra choisir des voies nouvelles en partant de la réforme des esprits pour en finir avec ce scandale et pour pouvoir ainsi libérer le monde de l'anxiété qui l'opprime et lui rendre une paix véritable d° 81,2
Qu'on évite donc ce scandale: alors que certaines nations ... jouissent d'une grande abondance de biens, d'autres sont privées du nécessaire d° 88,1.

* l'option préférentielle pour les pauvres est dans la vie de chacun le critère de sa réussite à unir politique de paix (désarmement) et développement. L'échec de notre civilisation serait de ne pas réintégrer les plus pauvres dans la société pour faire également d'eux les bénéficiaires de la croissance. Or non seulement l'ordre mondial actuel tolère l'existence de ceintures de misère autour des villes mais sa loi interne de développement est telle qu'il secrète de nouveaux pauvres. L'erreur de la lutte contre la pauvreté vient de ce qu'elle se donne pour objectif d'aider tel homme, telle famille alors que ce sont ceux qui sont enfermés dans l'exclusion depuis des générations qu'il faut prendre comme un peuple, dont il faut écouter les doléances et satisfaire les besoins. Ce

ne sont pas des individus qu'il faut tirer de leur condition infra-humaine; il faut procéder, en priorité des priorités, à une réorientation de nos activités en fonction de leurs besoins. L'on parviendra à une réduction significative des armements et à une reconversion du nucléaire non pas en marchandant des concessions réciproques, mais limitées, mais en démontrant que les économies qui en résulteraient sont la condition sine qua non d'une meilleure intégration de la famille humaine et donc d'une confiance plus grande entre les peuples et leurs gouvernements, gage de paix.

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Le débat sur les valeurs, le désarmement et le développement ne porte pas sur des questions abstraites. Dans la mesure où il se dévoierait sur ce terrain, il serait manqué. La situation où nous sommes est complètement nouvelle. Pour la première fois, grace à la démocratie, l'homme est devenu partie prenante aux décisions qui engagent le destin de l'humanité; mais il ne s'agit pas là d'un pouvoir qu'il aurait conquis pour devenir acteur dans l'ordre politique et dont l'exercice ne l'engagerait pas personnellement. Bien au contraire, chacun est invité à une conversion personnelle, intellectuelle et morale. Intellectuelle, car il doit se sentir heurté au plus profond de lui-meme par le désordre que constitue l'existence et le développement de la misère, de cette misère, qui cotoie la richesse; morale, car il doit commencer à se convertir lui-meme en repoussant à la marge tout ce qu'il peut y avoir dans ses comportements, individuels et professionnels, de complicité avec cet état de choses. Bien mieux, il doit chercher à réaliser, là où il est, dans les décisions qui dépendent de lui, au niveau qui est le sien, cette réintégration des populations marginales dans la communauté des hommes. C'est à ce prix, que nos discours sur valeurs morales, désarmement et développement descendront des sphères de l'abstraction vers l'établissement d'une nouvelle société.

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Nuclear Disarmament Process: A Global View

"Steps Towards the Elimination of Almost All Nuclear Warheads"

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STEPS TOWARD THE ELIMINATION OF ALMOST ALL NUCLEAR WARHEADS

by

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Views of the author, not of his organizations

Brief Biography of Richard L. Garwin
November 23, 1991

Richard L. Garwin was born in Cleveland, Ohio, in 1928. He received the B.S. in Physics from Case Institute of Technology, Cleveland, in 1947, and the Ph.D. in Physics from the University of Chicago in 1949.

After three years on the faculty of the University of Chicago, he joined IBM Corporation in 1952, and is at present IBM Fellow at the Thomas J. Watson Research Center, Yorktown Heights, New York; Adjunct Research Fellow in the Kennedy School of Government, Harvard University; and Adjunct Professor of Physics at Columbia University. In addition, he is a consultant to the U.S. government on matters of military technology, arms control, etc. He has been Director of the IBM Watson Laboratory, Director of Applied Research at the IBM Thomas J. Watson Research Center, and a member of the IBM Corporate Technical Committee. He has also been Professor of Public Policy in the Kennedy School of Government, Harvard University.

He has made contributions in the design of nuclear weapons, in instruments and electronics for research in nuclear and low-temperature physics, in the establishment of the nonconservation of parity and the demonstration of some of its striking consequences, in computer elements and systems, including superconducting devices, in communication systems, in the behavior of solid helium, in the detection of gravitational radiation, and in military technology. He has published more than 200 papers and been granted 41 U.S. patents. He has testified to many Congressional committees on matters involving national security, transportation, energy policy and technology, and the like. He is coauthor of many books, among them Nuclear Weapons and World Politics (1977), Nuclear Power Issues and Choices (1977), Energy: The Next Twenty Years (1979), and Science Advice to the President (1980).

He was a member of the President's Science Advisory Committee 1962-65 and 1969-72, and of the Defense Science Board 1966-69. He is a Fellow of the American Physical Society and of the American Academy of Arts and Sciences; and a member of the National Academy of Sciences, the Institute of Medicine, the National Academy of Engineering, the Council on Foreign Relations, and the American Philosophical Society. The citation accompanying his 1978 election to the U.S. National Academy of Engineering reads "Contributions applying the latest scientific discoveries to innovative practical engineering applications contributing to national security and economic growth." He was awarded the 1983 Wright Prize for interdisciplinary scientific achievement, and the 1988 AAAS Scientific Freedom and Responsibility Award.

From 1977 to 1985 he was on the Council of the Institute for Strategic Studies (London), and during 1978 was Chairman of the Panel on Public Affairs of the American Physical Society.

His work for the government has included studies on antisubmarine warfare, new technologies in health care, sensor systems, military and civil aircraft, and satellite and strategic systems, from the point of view of improving such systems as well as assessing existing capabilities.

In this paper I want to focus on questions rather than answers, the answers we hope to provide during this symposium. Some of the questions can't be answered in detail here or even without further work, but it is important to record and even discuss the questions.

Introduction.

There are some 50,000 nuclear warheads in the world, more than 96% in the armories of the U.S. and the former Soviet Union.

Almost all of these will be demilitarized and destroyed (more than half, in any case) pursuant to the initiative of President George Bush announced September 27, 1991, to which President Gorbachev of the Soviet Union responded in a few days, which commitments Boris Yeltsin, President of Russia, assumed in a speech of January 29, 1992.

According to widely published estimates, the US and Russia each have 100 tons of weapon-grade plutonium and 500 tons of highly enriched uranium (HEU) in their nuclear weapons.

As a consequence of his initiative of 09/27/91, Bush envisages some 4700 strategic warheads on each side and less than 1000 tactical warheads, justifying the presumption that our task is to consider the destruction of "almost all" nuclear warheads. According to President Yeltsin, there will remain only about 3000 strategic warheads, and he hopes that the numbers can be reduced well below that.

The urgency behind these reductions is the real hazard to the world of the presence of tens of thousands of warheads, any one of which exploding in a good-sized city would kill 500,000 people in a few seconds. These days it does not take much imagination to recognize factions and movements which would put to death the historical opponent if the means to do so could be obtained by purchase or theft, and threats might be posed by even less fanatic groups.

The recognition of declining marginal utility of large numbers of nuclear weapons can not lead simply to the abandoning of the excess, in view of the enormous hazard posed by intentional or accidental detonation, and the large amounts that might be paid (hundreds of millions of dollars, or more) for the first few warheads that could be transferred in usable form from the US or Russian stockpile.

Concern for the economy and for the wealth of the world's people makes it important and potentially profitable to investigate what can be done with the durable elements of the stock of warheads, namely the fissionable material.

The world can't recover the vast expenditures made to create the materials and to fabricate the warheads, and society will have to pay the environmental damages and cleanup costs of the military nuclear energy programs, particularly in the former Soviet Union. Nor is the stock of fissile material-- HEU and Pu-- different in kind from fuels available for power reactors; it is not uniquely valuable. Clearly HEU can be burned in existing light-water reactors (LWR) which use ceramic fuel in which the fissile naturally occuring U-235 isotope is enriched to 3% or so rather than the 0.7% natural abundance. Military HEU of 93% U-235 and only 7% U-238 can readily be diluted with either natural or "depleted" uranium to the required 3%. Dilution with enrichment "tails" containing 0.25% U-235 would require about 34 kg of depleted uranium (DU) per kg of HEU, but the result would be identical with the common 3% low-enriched uranium (LEU) which is a valuable commodity for preparation of LWR fuel.

Fissile uranium does not decay spontaneously for hundreds of millions of years, and weapons plutonium will be as useful for nuclear weapons thousands of years hence as it is now. Yet the world LWR economy produces now some 70 tons per year of Pu in the normal operation of the reactors; neutrons from fission of U-235 are captured in the 97% of the fuel metal that is U-238, producing more fissile Pu. Indeed, existing plants for fabrication of "mixed oxide" fuel for LWR ("MOX") have an annual world capacity now of 88 tons of metal, with additional annual capacity of 260 tons per year in France, Germany, and Japan, and 120 tons per year being built in Russia.

The 70 tons of Pu produced annually by commecial reactors would need some 2000 tons of uranium for dilution to MOX, so that there is by far inadequate MOX capacity to handle "reprocessing" of spent fuel to MOX. If the MOX capacity of 400 tons of metal per year were turned entirely to the conversion of the 200 tons of military plutonium (plus 7000 tons of diluent uranium), it would take some 18 years to convert to MOX.

Conclusion 1: Assuming that we wish to preserve the HEU and military Pu for the production of energy for the civil economy, we will need to store at least the Pu in some form for a decade or more.

Question 1: What are the costs of adequately secure storage of Pu (and HEU) in various forms-- in intact but disabled nuclear warheads, as metal "pits" extracted from nuclear weapons and perhaps crushed or distorted so that it could not be easily re-used in a standard warhead, as Pu alloyed with uranium metal perhaps to 20% Pu concentration so that it could not be made critical in any size?

Even 20% Pu in uranium could readily be processed chemically to separate the Pu from the uranium, but that would take some time in comparison with fabrication of existing military Pu. Of course, 20% U-235 in uranium would need substantial isotope separation to make HEU, not an order of magnitude different from starting with LEU as feed stock.

Question 2. What would be the investment and operating cost (and time to build) a facility for safely alloying HEU or military Pu with uranium, if the storage cost of such neutronically safe material were estimated to be substantially less than that of material usable in nuclear warheads?

Economic aspects.

A typical LWR (of 1000 MWe or 1 GWe) uses about 1 ton per year of U-235, so that the world's reactor population of about 400 reactors and 300 GWe uses about 300 tons per year of U-235. Evidently fuel fabrication capacity exist to feed these plants, so that the assumed 1000 tons of HEU could be consumed in a bit more than 3 years of operation, if HEU totally replaced enrichment for that time. This would be disruptive of the market, and the HEU price would presumably be driven down if it were forced onto the market with the necessity of using it immediately. But the time value of money is different for different groups (as is the need for cash), and there is a need to answer

Question 3: Given different costs for storage, safeguarding, preprocessing, and fuel fabrication, what are likely scenarios for the purchase, sharing, lease, or other transfer of weapons HEU to the civil market?

Question 4: Since fuel is a small part of electricity costs from an LWR and an even smaller part of total cost of a fast-neutron ("breeder" or near-breeder) reactor, under what conditions is there a net benefit in retaining the HEU until the breeder population grows far above the present few reactors? HEU is in general an initial fueling option for breeders that will allow rapid expansion of a breeder population, whether the HEU (or MEU) is obtained by dilution or by enrichment.

Of course, normal breeders by definition do not "destroy" plutonium. The problem with introduction of breeders is high capital cost even in comparison with LWR; how will breeders help to solve the plutonium problem?

Any reactor will convert military plutonium that can be held in the hand safely (if appropriately plated) or in a glove box, into fiercely radioactive material heavily contaminated by fission products.

It is believed that reprocessing of LWR wastes to recover Pu and uranium for fabrication of LWR fuel is uneconomic per se, but is justified by legal requirements in some localities, or for other reasons sometimes characterized as "independence." However, most spent fuel goes unprocessed and (in the United States at least) will be committed to geologic storage without extracting the Pu. Which brings us to

Question 4: If reactor wastes are to be buried without reprocessing, and use of MOX from military plutonium is not highly rewarding in itself, how practical is it and what would be the cost of blending military Pu with reactor spent fuel as it is glassified or packaged for geologic disposal? The purpose would be to reduce the cost of safeguarding the plutonium against theft or diversion over a period of years, decades or centuries.

Concluding remarks.

Given the importance of energy to the people and the economy of the world, it is important to choose a path for the conversion of military stocks of HEU and plutonium to electrical energy, which will provide economic benefit or at least minimize the disposal cost. But unlike a stock of coal or even gold, the loss of even 1% of the fissile material, in the form of rogue nuclear weapons, could outweigh the economic value of the energy of the entire stockpile. It is this which gives the problem the urgency and importance that has brought us here.

FONDAZIONE PER LA PACE
E LA COOPERAZIONE
INTERNAZIONALE
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S T E S

SCIENZIATI E TECNOLOGI
PER L'ETICA DELLO SVILUPPO

(6)

International Symposium
on
"CONVERSION OF NUCLEAR WARHEADS FOR PEACEFUL PURPOSES"

Palazzo Doria - Rome
June 15-17, 1992

Outlook of a Safe and Feasible Conversion Responsabilities of International Organizations

"International Scientific Cooperation in the Disarmament Process"

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INTERNATIONAL SYMPOSIUM

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INTERNATIONAL SCIENTIFIC COOPERATION IN THE DISARMAMENT PROCESS

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ENEA, Rome, Italy

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1. Introduction

The great events in the former USSR (now CIS) and in Eastern Europe (which will collectively be indicated in the following as "the East"), and the tendency towards a greater integration between East and West have important consequences in the domaine of science and technology. Science and technology represent, through innovation, one of the main motors to revitalize Eastern economies. New technologies are needed to improve the efficiency of production in the East and to reduce the negative impacts on the environment (including global impacts). Preoccupations concerning the future of nuclear weapons scientists in the CIS and their possible role in horizontal proliferation are a related subject which has found great echo in the media.

The cooperation in science and technology between East and West is therefore an important element in the process of shaping the new world which replaces the vertically divided world of the Cold War, based on mutual deterrence and mistrust. As we shall see, it is a subject full of difficulties as well as of opportunities, and several initiatives are being discussed at this moment. A review of this process seems therefore justified today.

2. Science and Technology in the East

In the East, and in particular in the USSR, scientific research had reached in many sectors a level comparable to that of Western science, with notable points of exellence especially in theoretical disciplines (such as mathematics and theoretical physics) and in those fields in which a direct competition with the West had been engaged (such as space and defence).

In the East, the importance of science for the development of society was officially recognized. Scientists had high salaries, prestige, and a privileged status, including greater freedom of movement. With a number of important exceptions (like the case of Lisenko) in which ideological considerations were imposed to distort the scientific process, in most cases scientists were left free to conduct their research. In the most prestigeous institutes, even political pressures and the subordination to party indications left room for competence and scientific merit in the choice of the leaders.

In the East, most scientific research was (and still is) organized through the Academies. In each of these countries, the Academy of Sciences played a triple role (in the sense that in the West these roles are covered by three different institutions): that of a Ministry of Basic Science, with its President, or Scientific Secretary, often being a member of the government; that of an operative structure including (in the USSR) hundreds of laboratories and institutes, some of a very high scientific level, and with a slightly elitarian flavour; and that of a learned society, with influence on the intellectual sectors, much as the Academies of the West. Academicians had little or no teaching burden (a fact which was considered as a privilege but may also have had drawbacks), while comparatively less research was carried out in the universities, generally mostly devoted to teaching. More applied research would refer to other institutions, such as the All-Union Committee for Science and Technology (GKNT) in the USSR, and the institutes depending from the various ministries.

In any case, particularly in the USSR, the scientific and technological system was heavily conditioned by the high priority given to the military sector in the allocation of financial resources, scarce scientific equipment and high-level scientists. This would also influence the relative development of the various disciplines.

It is too early to say whether the main structure of research, and in particular the role of the Academies, will remain the same in the future. Many criticisms have been raised in the East and proposals for radical changes advanced. The outcome is still uncertain, and a reform of the scientific system is probably not a first priority in the political agenda. However, it should be noted that the deficiencies of science and technology in the East, which we will shortly deal with in the next section, cannot be attributed (at least primarily) to the structure of the research system. Although changes are needed, it would probably not be advisable to copy the type of organization which exists in the West (or, rather, in one or another of the Western countries). Conditions and requirements are different, historical developments cannot be ignored, diversity has its value, and lessons can be learnt also from the shortcomings of other systems.

3. Limits of the R&D systems in the East

Despite the high level reached in several sectors, the research systems in the East suffered from serious limitations which resulted in reduced effectiveness. The limits in the availability of advanced equipment (in particular the lack of access to high performance computers, except in the military and space sectors) were real but certainly not the most important ones.

More serious limitations derived from the lack of connections between research and application, and from the absence of an evaluation of the economic, social and environmental implications of new technologies. The lack of diffusion of the results of research was at least partly due to the absence of a market. This also influenced the choice of the lines of research. A tendency which was (and perhaps still is) very common is to seek solutions to immediate problems by developing very advanced technologies, when there is no capability of applying and diffusing much simpler solutions which are already widely available. The assignment of priorities often appears to be haphazard, or linked to opportunities for research rather than to a ranking of importance of solving actual problems. In the absence of market signals, planning was unable (or did not even try) to fill the gap.

Moreover, and somewhat paradoxically, just in the so-called centrally planned economies there was very little long-term planning of the development of science and technology. There was in general a nearly blind trust in science and in the capability of the central system to plan technology so as to solve the problems of society. In reality, however, no serious "technology assessment" was carried out, in the sense of predicting, analysing and evaluating the economic effects, the social consequences (in terms of occupation, distribution of labour skills, improvement of social equality or creation of disequalities, of condition of women etc.), on international relations, on environment, on health, and even on politics, deriving from the development and diffusion of a given technology. This was, as I said, a paradox, in the sense that planned economies had all the instruments for taking decisions on the basis of such evaluations, whereas in the West technology assessments are common, but the application of their results is less direct.

The consequences of this lack of strategic assessment of technologies are obvious in many fields. The degradation of the environment has reached unacceptable levels. The energy and material intensity of the gross national product is nearly double that of other industrial countries, and the average efficiency of energy use corresponds to situations and technologies of 50 years ago: and this is certainly not the consequence of effective technologies not being available (at least at the level of laboratories) but of the fact that there was no incentive to introduce them.

4. Crisis of the research institutions in the East

In the presence of a serious economic crisis, scientific and technological research, which yield few immediate returns, are in a difficult situation in most Eastern countries. This situation puts in question the survival of many high-level research groups. In these countries, financial allocations to research institutions are often constant (if not decreasing) in monetary terms, and therefore take no account of the high rate of inflation (500% in one year in the CIS). Salaries for scientists, which remained nearly constant, have fallen below the average salary in the country and often below the vital minimum. No money is left for equipment and operation of the laboratories. Some research institutions have started dismissing personnel (often on arbitrary bases), while others have tried to start projects for the nascent private sector, often with little scientific content. The brain drain towards other countries has so far been limited, but is a real menace for the future; more relevant is the internal brain drain, towards business oriented activities, where possibilities of earning are by far greater.

This dire economic situation is compounded with political difficulties; in the various countries, different research institutions have met with varying degrees of mistrust when they were, rightly or wrongly, supposed to have opposed or resisted the political changes. In addition, the process of territorial disgregation (in particular, but not only, in the CIS) has generated or is generating difficult reorganizations, lack of decision power and internal contrasts.

5. The conversion of the military apparatus

The problem of the conversion of the military sector to civilian objectives is strictly linked with the problems of the research system: in the military sector, at least in the CIS, is concentrated an important part of advanced research and modern technology capabilities. A conversion that frees these forces for a civilian productive activity and for economic recovery is a fundamental condition for redressing the economy. This conversion is not without problems. A dispersion of this pool of scientists and technicians among existing non-military institutions would not allow for a long time to fully exploit their capabilities and would destroy sinergies. A brain drain of scientists with strategic know-how in the weapons sector towards unreliable countries could be dangerous for further proliferation and is today a major worry in the West.

A transformation of the military apparatus towards other objectives that keeps its unity puts in question the continuity of the military control over these activities. It is not easy to find new objectives for the specialized know-how existing in military institutions (space, telecommunications, environment? but also production of goods of large consumption, energy efficiency etc.). It is to be noted, however, that the defense complex in the USSR was already engaged in civilian production: a large share of TV sets and refrigerators were already produced by military establishments!

The problem of conversion and that of research are often linked together, also at the political level: in several cases there is one ministry or one parliamentary commission dealing with both subjects. This problem receives a high amount of attention from all parts; several bilateral or multilateral meetings on the subject were held in Europe and in the United States. by a message from Gorbacev. A certain number of developments that had taken place in the frame of defence programmes and that were previously classified have been disclosed, and their utilization for peaceful purposes has been proposed.

The conversion, indeed, is not easy also in the West, and here mostly because who generally works for military clients is used to very high production standards but is less used to market signals, to international competition and therefore to minimizing costs. In this sense, one can understand the efforts of the US administration to keep as much as possible of the SDI initiative, and the proposal discussed by Bush and Eltsin for a joint programme of a common global defence system (which makes very little strategic sense in the opinion of most experts).

6. East-West cooperation on science and technology

The West has good reasons to support Eastern science and technology. First of all, there is a general political interest in sustaining the process of democratization and move towards a competitive market: this process needs an acceptable economic situation to be affirmed and stabilized, and the economy needs modern and effective technologies.

There is also an environmental interest, which applies in particular to the energy sector: the environmental degradation produced by the use of inefficient technologies and by the lack of a market system has consequences that are not limited to the East, but have continental dimensions, as in the case of acid precipitations induced by the combustion of poor quality coal or oil without appropriate filtration systems, or the radioactive fallout following the Chernobyl accident, and global dimensions for CO_2 emissions and the greenhouse effect. And, finally, there is an interest in the widening of the market, as foreseen for instance by the European Energy Charter, which allows to exchange raw materials which are abundant in the East (and which today are often poorly exploited and utilized) with advanced technologies and high-tech products.

There is also an understandable interest from the East to receive support for their research, not only in terms of financial help, but also as suggestions and cooperation in identifying the objectives of research, in carrying out evaluations (ex-ante and ex-post), in setting up new organizations for science and technology. The numerous requests to help set up international peer review systems for various kinds of science and technology projects originating in the East is paradigmatic in this respect.

A strict cooperation between East and West in the field of science and technology could help research groups in the East to overcome their present survival problems, to address their activities towards more useful goals and acquire the enormous scientific and intellectual potential of the East for joint research programmes.

Problems have to be solved and difficulties overcome in order to do this. Talking in particular about Europe, the first problem is of a deep political nature. The European Community is at a critical step in creating its single market. In what direction should it move in the next ten or fifteen years: in the direction of broadening its territorial basis towards the EFTA countries, then Eastern Europe, the CIS and eventually the Mediterranean? Or rather in the sense of strengthening the cohesion among the present members of the Community, of creating political union beyond the economic union? The debate on this dilemma - breadth versus depth - is central on the European scene today. The compromise solution emerged at the Maastricht summit: one can work in both directions, by imagining a Europe of concentring circles, an "inner core" with increasing political unity, and outer rings which are progressively more loosely bound, mostly through the creation of a common market area. If this principle is acceptable to everybody, the relative emphasis to be given to broadening versus deepening is still controversial, and it is likely to pose problems in the presence of limited resources.

The Commission of the EC already has programmes in support of the East that are open to research projects, such as PHARE, which however until now is not open to the countries of the CIS, in the absence of bilateral agreements between these countries and the CEC; but these programmes are based on priorities which are determined by the receiving country. So far, Eastern countries have generally assigned priorities to sectors that were perceived of more urgent need than science and technology, and little funds have been allocated to research (30 Mecu out of a total of 760 Mecu, and mostly to Hungary). The same situation often applies to other bilateral or multilateral initiatives, when science and technology has to compete with more urgent needs. It is therefore necessary to set aside a part of the funds (even a relatively small share) for research projects, seen as wise investment for the longer term. Moves in this direction are being made, and this has already been the case - as we shall see - for the EC funds devoted to technical assistance (450 Mecu of which are earmarked for the CIS). A new programme for R&D cooperation with the East is expected to be approved by the CEC shortly: it will have for 1992 a budget of 55 Mecu, 40 of which for the mobility of scientists and exchange of information (15 for exchange of scientists, including "shuttle grants"; 5 for information networks and 20 for joint research actions), while 15 will be devoted to support the participation of Eastern scientists and institutions in the EC research programmes (on environment, energy, medicine and mobility) and to COST actions. Application will be open to individual scientists and institutions and, as in the other cases of EC R&D programmes, the selection will not be based on priorities assigned by governments but on the decision of the Commission, acting on the advice of a peer review group, including scientists from the East and the West.

The European Energy Charter has no special provision for research. Russia has objected to this situation, but the answer has been that the main objectives of the Charter are short-term, and that the priority is to transfer as soon as possible energy technologies that are already available. Although this makes sense, it takes little account of the necessity of adapting existing technologies to different contexts (which involves research and development) and also of the opportunity of using technologies that have already been developed locally near to the final step. Possibilities of introducing research cooperation in the Energy Charter still exist for at least one of the protocols being discussed, the one on energy efficiency; in the case of nuclear energy, the Charter concentrates on the safety of existing installations and does not include the possibility of joint work on future, safer reactors (such as intrinsically safe reactors).

East-West cooperations in the field of "big science" are possible and are already taking place. Close contacts have been the rule in high-energy physics, for which Russia has in Dubna one of the major laboratories at the world level. An initiative to fully open to the East the European Centre for Nuclear

Research (CERN) is under way. A recent NATO seminar (Schloss Dagstuhl, August 1991) has suggested that East-West cooperation in science and technology could start from physics, since research in physics has always been "internationally oriented". It is also true, however, that physics, and in particular high energy physics, is less of a first priority worldwide and that, while instrumental in establishing a high scientific level and in promoting some advanced technologies, it is less directly linked with industrial development and production problems than other fields of science, such as materials science, biotechnology and informatics.

In the field of nuclear fusion, a four-party (EC, USA, Japan and CIS) project for the design of the ITER fusion Tokamak is already underway; if this machine will actually be built, it will represent the largest international research project of all times. Russia has taken up for the CIS the former USSR engagements. The US has recently announced a programme to support the Kurchatov Institute in its work on nuclear fusion, in particular in connection with the work on ITER, through a research contract of 90,000 $ to help with the expenses for 116 scientists; although this may seem a negligible sum, it does help in the present circumstances.

In order to help Eastern research and to prevent brain drain, two complementary courses of action have been suggested.

The first is to offer temporary (and preferably periodical) working opportunities in the West to Eastern scientists retaining their position in their research institution. By alternating periods of work of some months each in the West and in the East, several results are obtained: the West can obtain the contribution of highly qualified scientists from the East to fill up gaps and to enrich the range of ideas, paying for this at competitive market prices. Eastern scientists can work effectively while in the West, with equipments and infrastructures that often are not available in the originating laboratories (especially in the field of advanced computers), with easy and unlimited access to literature. In the periods in which these scientists work in the East, they can use the extra money set aside in the West, which even if modest in Western terms, can make a difference being in hard currency. The collaboration offers to the institutes in the East subjects of cooperation with the West which are of common interest and often have applicative outcomes; links are thus established that will be of reciprocal advantage to both parties when the situation in the East will have stabilized. Some such initiatives are already under way: for instance the Landau Institute in Moscow has established agreements with several institutes in the West following this scheme. The forthcoming

R&D cooperation programme by the CEC that I have mentioned previously will support the assignment of such "shuttle grants".

The other course of action is to set up, in Eastern countries, research initiatives financed by the West on subjects agreed together.

In mid-February, the foreign ministers of USA, Russia and Germany (Baker, Kosyrev and Genscher) agreed in principle on the creation in Moscow of an International Centre for Science and Technology, that in the original statement was meant to "support scientists and engineers from the former USSR in this critical period, which includes the transition to a market economy, the current desarmament process and the conversion of the industrial and technical potential from military to peaceful purposes". More than a research centre, this institution should be a focal point for the development, the selection, the financing and the follow-up of research projects, to be carried out mostly by institites and laboratories located in the Russian Federation and in other interested states of the CIS. The agreement to set up this Centre was signed in Brussels on March 11 by the US, Russia, the Commission of the European Community and Japan. US and Europe are engaged to supply an initial investment of 25 M$ each, while Japan is expected to contribute with 10 M$. Russia has offered to locate the premises of the Centre at Troisk, in the neighbourhood of Moscow, on the site of a previously military research centre. In the meantime, the main focus of this initiative has been concentrated on the reorientation of the activities of former weapons scientists, in particular of those engaged in reasearch on mass destruction weapons: nuclear, chemical and bacteriological. The original intention of using this initiative "to sustain the transition to market-based economies that respond to civilian needs, and to support basic and applied research and technological development" seems to be considered only in the frame of the conversion process, as a consequence of the reorientation of military research activities. Details of the organization and of the activities of the Centre will be discussed in the next future.

This is not the only initiative being discussed. The Nobel Prize for physics and director of CERN, Carlo Rubbia, had proposed already last September the institution of a foundation to be financed for 50% by Europe and for 50% by USA, Canada and Japan. The objective was to help for 10 years, with 100 million dollars per year, about 5000 Eastern senior scientists. The sum should be used to integrate their salaries, to acquire informatic hardware and software and scientific literature. It should be targeted to specific research projects and by-pass all red-tape. This plan has met with the approval of French president Mitterrand, and should be presented to the next meeting of the G7 (heads of state of the most industrialized countries) at the end of this month. This proposal is distinct from the previous one in that it is not directed specifically towards weapons scientists, and its main purpose is to support basic science in the CIS.

Other proposals have been made in different contexts. For instance, in the frame of the Hexagonal initiative (Italy, Austria, Yugoslavia, Hungary, Chekoslovakia and Poland) a number of joint initiatives are being discussed, ranging from particle accelerators to solid state physics.

Finally, I should like to mention the proposal to set up in the West a few laboratories or focal points for the testing, qualification and adaptation of research results coming from the East in view of their commercial applications. Many good proposals coming from the East (in part as a consequence of declassification of military research) could find applications in the West, but their diffusion is limited by the fact that they were born in a different environment, and may not be directly applicable in a Western context, as concerns industrial practices, quality controls, standards as well as market preferences. The role of these institutions would be to facilitate the penetration of such proposals in Western industries and markets by a process of qualification and adaptation.

7. Conclusions

A Western support of Eastern science and technology is essential in this difficult transition period. This support must keep the integrity of the best research institutes in the East, it must provide sufficient incentives for Eastern scientists to work in their home countries and it must help converting weapons scientists to peaceful and useful objectives. It must also preserve the wealth of ideas and the originality of science in these countries: as underlined by a recent CEC study, diversity within Europe (and in particular between East and West) is a value at risk, which should be preserved because it is an important part of our cultural richness.

Initiatives under way are positive and useful, but they do not cover the whole range of needs. In particular, apart from the fundamental problem of the conversion of military research, the emphasis is on basic research, and on physics in particular. This is good but not sufficient. Help in directing applied scientists and technologists to outcomes that are of actual interest for the transformations taking place in these societies is also needed. The lack of technology assessment, of evaluations, and of market signals must be made up for appropriately.

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NUCLEAR WARHEADS CONVERSION PROJECT

General Objectives.

The symposium agenda speaks for itself as an indication of radical changes going on in the world. The social stereotype of the cold war times is becoming a thing of the past. The contemporary world development realities have shown that the aspiration to possess a powerful nuclear arsenal which was till recently considered the security guarantee can a deadlock and lead to an enormous stockpiling of nuclear weapons the very existence of wich is fraught with grave threat for mankind. In view of all this it is obviously indispensable to comprehensivly solve the problem. The solution must include political, economic, legal, scientific, technical and other measures spearheaded to block off and eliminate both the war-mongering tendencies and war-waging material and technological basis, first and foremost in the sphere of nuclear weapons.

But the disarmament policy can be actually pursued only in the atmosphere of complete and mutual understanding and confidence on the part of all members of world community and of step-by-step concordance of positions that frequently differ considerably. Hence a series of peaceful initiatives suggested by our governing body.

There is no much sense in enumerating all initiatives moved by the leaders of many nations. It is well worth mentioning only some of them, the most substantial ones, suggested in recent years. These include:

- strategic offensive arms reduction and limitation treaty signed by USSR and US Presidents (July 1991, Moscow);
- the US President's statement on nuclear arms reductions (September 1991);
- the USSR President's statement on further nuclear arms reductions (October 1991);
- the RSFSR President's statement on Russia's policy in the sphere of arms reduction and limitations (January 1991);
- the US President's statement on further nuclear arms reductions (January 1991).

The treaty signed in Moscow in July 1991 by the USSR and US Presidents makes for the first time in history provisions not only for limitations but for reductions of strategic nuclear arms. According to the treaty provisions total number of deployed intercontinental ballistic missiles, submarine-launched ballistic missiles and heavy bombers will be reduced to 1600 units for each party and total number of warheads for them - to 6000 units respectively.

The unilateral initiatives stated by M.Gorbachev in October 1991 envisage the following aditional measures:

- liquidation of all nuclear artillery projectiles and nuclear warheads for tactical missiles;

- withdrawal of munitions for surface-to-air missiles from the armed forces and their stockpiling on storage bases;

- liquidation of all atomic demolition munitions;

- withdrawal of all tactical nuclear weapons from surface ships and multi-purpose submarines and of naval aviation nuclear weapons as well;

- discontinuance of heavy bombers war alert flights with nuclear weapons aboard;

- development halt of heavy bomber-based short-range nuclear missile and mobile small intercontinental ballistic missile;

- banning on increase and retrofit of intercontinental ballistic missile rail garrison launchers, deployment of all our rail intercontinental ballistic missiles at their permanent basing locations;

- retirement of 503 intercontinental ballistic missiles, including 134 ones armed with multiple independently-targetable re-entry vehicles;

- retirement of three nuclear submarines with 45 ballistic missile launchers and three ones more with 48 ballistic missile launchers;

- reduction, after the expiry of seven-year term , of strategic nuclear warheads number to 5000 unis;

- announcement of unilateral one-year moratorium on nuclear tests;

- proposal to carry on a dialog with the USA on the subject of developing safe and ecologically responsible technologies for nuclear weapons storage and transportation, nuclear materials utilization and upgraded safe storage;

- reduction of the total armed forces personnel by 700,000 men.

In January, 1991, the RSFSR and US Presidents moved again, practically simultaneously, the initiatives to reduce their nation's nuclear potentials, Russia being announced the legal successor to the USSR in the sphere of international commitments.

President B.Yeltsin's proposals included:

- strategic offensive arms treaty ratification;

- retirement of 600 ground-and sea-based ballistic missiles (1,250 nuclear warheads);

- liquidation of 130 silo launchers and dismantling of launcher tubes on six submarines;

- development halt of several strategic arms types;

- breaking up at an earlier date the specified number of strategic nuclear weapons in the Ukraine;

- production halt of Tu-160 and Tu-95 MS heavy bombers and sea- and air-launched cruise missiles as well.

The qualitative analysis of the latter proposals show that for the first time the initiatives embrace practically the whole range of nuclear weapons, both active and being developed ones. The proposals actually suggest to liquidate the majority of tactical and battlefield nuclear weapons. The initiatives while limiting the ranges of nuclear weapons employment pose rather complex problems connected with the conversion of nuclear weapons and production thereof.

The conversion problems when approached generally can be solved in the following ways:

- giving any military production up and switching over to civil production only;

- partial conversion, i.e. switch-over to non-military production and freezing of highly specialized capacities on the production lines using technologies similar to civil production;

- increasing the portion of national economy goods in the total volume of production output as a result of some production space reconstruction.

The conversion however must take into account not only economic aspects but strategic stability basis preservation as well. That is why when carrying the conversion out the following imperatives should be borne in mind:

- ensuring by all means the fulfilment of adopted and current armament programs;

- barring the parity break-up and strategic stability maintenance;

- creating the "insurance" fund that must make up for possible reconversion expenditures.

A certain scientific and technical reserve in case of reconversion emergency could quickly help set things going in turning out novel military hardware because elimination of possible strategic stability disbalance that can emerge as a result of one of the nation's actions cannot be implemented using the quantitative production increase only.

President B.Yeltsin in his interview to "Izvestiya" (February 1992) said that the part of the funds released from defense expeditures will be forwarded to directly finance the conversion. Russia strives for nuclear disarmament but for the disarmament on the principles of parity and not a unilateral one.

There are some specific questions in the conversion problem connected with the nuclear weapons liquidation and restructuring respective industries for national economy goods production. It should be borne in mind that nuclear activities is a specific and unique branch of science and industry which has no analogy to anything. And all these must to some extent be preserved for a time because practically all nuclear nations do not want so far to give up nuclear weapons and in the near future we may face the emergence of new nuclear club members.

Special attention should be paied to the fact that nuclear powers do not plan at present to suspend or curtail their research in the field.

The number of nuclear warheads being designed reduces but it is planned to intensify the research in advanced areas of their modernization. Two situations may arise in connection with nuclear weapons design:

- the development and production of nuclear weapons is going on;

- the development and production of new nuclear weapon models is stopped but the existing nuclear weapon models are still being used in the armed forces.

The two situations must include the actions connected with the increase of nuclear weapons safety and must take into account the process of partial nuclear warheads retirement, in the first case because of the end of the guarantee period and because of the realized government initiatives in the other case.

In the first situation the development and production have no changes, the second situation requires only partial closing and reequipment of the main industries, since the nuclear weapons operation needs periodic replacement of weapons parts produced on the nuclear industry plants. So the research and development must continue and first of all the works in nuclear weapons safety improvement.

The field tests are of particular interest in the working off and improvement of nuclear explosives. The nature of physical processes taking place at the moment of nuclear explosion is such that can practically never be calculated by any perfect calculation methods, any complexes or any modern laboratory methods possibilities and the only way to achieve significant results is the field tests.

The nuclear warhead safety conditions can hardly be evaluated without the field test and it is difficult to give any recommendation to increase safety. The nuclear tests also provide of the nuclear potential that is being operated and stored. So the realization of nuclear weapons conversion can not be regarded without field tests even if the development of new nuclear warheads is stopped. No doubt these tests have to be secure and ecologically safe. Our position is to stop the nuclear tests if the USA, France, Britain and China will stop them too. It must be mentioned here that the US scientists reject practically every suggestion on stopping the nuclear field tests. Scientists working at the weapons laboratories have at their disposal, the best computer base and can achieve more accurate prediction results but they can not do without field tests.

It must be noted that before 1991 the preference had been given to the field tests developing new generation weaponry, but now the main task is to control stocks and improve safety measures.

The peace initiatives realisation requires the particular measures proving the nuclear weapons safety because of the increasing volume of transport and storage problems of active materials (especially plutonium) removed (even temporary) from the nuclear warheads.

The increasing volume of transport is caused by re-distribution of nuclear weapons between military groupings and utilization of nuclear warheads on a few existing plants. And there were no long-term plutonium storages because all plutonium was immediately used for the weapon production. Under conditions of nuclear arms limitation a special place takes the problem of non-proliferation of nuclear weapons and technologies.

Our government has signed a treaty of non- proliferation of nuclear weapons and follows its regulations thoroughly. The operation, storage and transport of the Soviet nuclear weapons abroad was performing only by our specialists. Warsaw Treaty military personnel was not allowed to operate the nuclear weapons. The enlisted personnel also are not allowed to have direct contacts with the nuclear warheads. So the number of personnel operating the nuclear warheads is strictly limited.

In nuclear industry only 2000-3000 persons have the access to the information, no casual people can be found among them. At the Ministry of Defense the number of military personnel knowing the details of a nuclear warhead construction is very limited and contains some thousands men. So the possibility of the information drain practically does not exist.

All the nuclear warheads at the Ministry of Defense are under strict control and serious protection so that no nuclear warhead or its component can be lost. When utilizing a nuclear weapons stoskpile a special attention is given to the problem of unauthorized actions with the nuclear weapons and the nuclear warheads. Nowadays the conception of unauthorozed actions prevention system was developed and is being realized in all phases of nuclear warhead life cycle. The unauthorized actions prevention sastem includes both the complex of technical means and the organizing measures to upgrade the security. The complex of technical means consists of:

- nuclear warhead protection means;
- nuclear warhead safeguarding means;
- the organization measures.

The technical protective means practically exclude the possibility of unauthorized actions with nuclear weapons by the terrorist teams or criminals. The technical safeguard means prevents the criminal from the access to the safegnavded object. The safeguard systems are organized so, that the technical safeguard means do not allow the access to nuclear warhead neither to terrorists nor to "bad guys" from the operating personnel.

The organisation measures include:

- the procedure of selection, check-up and access of the personnel to weapons work;
- the realization of principle called "sharing knowledge";
- the realization of principle called "two-three persons" at weapons work;
- periodical personnel testing in order to find out and remove the unreliable persons from the nuclear weapons work. The testing technique is developed and proven.

The realization of these measures of the unauthorized actions with nuclear weapons prevention upgrade the security so that no unauthorized actions can take place.

Speaking about nuclear weapons conversion the key question is the usage of enriched uranium and plutonium that come from nuclear warhead dismantling.

The agreements between states and the realization suggested by the US and Russian Presidents envisage a largre number of nuclear warheads limitation so that hundred of tons of enriched uranium (U-235) and tens of tons weapon-grade plutonium (Pu-239) will appear.

The weapon-grade uranium with different degree of enrichment can be processed for the nuclear power reactors (the degree of enrichement is 2-4 percent), for the transport and ship nuclear reactors (the degree of enrichment is 10-36%). Commonwealth of Independent States nuclear energetics demands for uranium -235 total about 50 tons a year at present. The nuclear energetics demands for uranium are provided mainly by regenerating it from irradiated fuel. The approximate amount of regenerated uranium-235 can be about 12-15 tons a year in the Commonwealth of Independent Itates.

In that way some uranium-235 "surplus" (the hundreds of tons), appeared from the dismantling of nuclear weapons, can be gradually used in nuclear energetics.

Nevertheless even partial using of weapon uranium in nuclear energetics will demand for changes in technological processes at the fuel elements of nuclear disarmament program will lead to the recovery of hundreds of tons of high enriched uranium , and only part of it can be used in the nuclear fuel cycle nowadays. The overall "absorption" of the weapon uranium by nuclear energetics will be possible during the next 15-20 years. It means that even in the case of the additional realisation of the part of the recovered uranium for export, the main problem for the mentioned period of time is safe and reliable storage of recovered after nuclear warheads dismantling enriched uranium .

The weapon plutonium can be used in fast neutron breeder reactors.But the number of these reactors is small and the demands for plutonium loading are not great. The more perspective is to use plutonium as a part of mixed fuel (Pu,U)O2 for light water reactors.

The new technology of fuel elements making from mixed fuel and their use in reactors is still in the phase of development.It's production is expected in 10-12 years.

In 1990 there was extracted approximately 40 tons of plutonium from Europe and Japan reactors irradiated fuel. For the Commonwealth of Independent States it may be stated the value of 10 tons.In the case of introduction of mixed fuel technology for the nowadays Commonwealth of Independent States nuclear energetics, the necessary amount of plutonium for fuel elements will make up approximately 20 tons. In this way mixed fuel new technology could have "absorbed" up to 10 tons of weapons plutonium every year.

Thus the whole amount of recovered after nuclear weapons dismantling weapons plutonium would have been utilized entirely during 5-10 years.

Both for weapons uranium and weapons plutonium the decisive is the problem of safe and reliable storage, because the realization of mixed fuel production technology will be possible only in 10-12 years and the plutonium burning in light water reactors will take 5-10 years more.

In this way it will take 15-20 years to utilize the whole amount of recovered uranium and plutonium in the bounds of the known or creating technlogies.

All the discussed general problems of nuclear weapons conversion and recovered uranium and plutonium storage after dismantling of nuclear weapons predetermine the conducting of scientific, research, development and testing works.

The purposes of these works are:

- the creation of safe technologies and equipment for fission materials processing;
- the setting up of nuclear safeguard system;
- the creation of monitoring methods and equipment to control the stored materials;
- the creation of nuclear, radiation and ecological securing methods and procedures;
- the creation of dismantling nuclear weapons materials used in nuclear energetics and other spheres of national economy.

As a whole, nuclear weapons conversion problem is a complicated scientific and technical problem. It is economically unprofitable, but the necessary measure.

One of the main foreign policy tasks of our state leaders was a fight for nuclear weapons stockpile reduction and elimination. The initiatives of our government were: nuclear weapons test ban in three spheres; underground explosions yield lowering; nuclear weapons non-proliferation treaty; short and intermediate range nuclear missiles liquidation and offensive strategic arms limitations agreements. Our Russian leaders took up on themselves all the responsibility for former Union of Soviet Socialist Republics nuclear stockpile. That is why the offensive strategic arms reduction and limitations treaty was followed by President's proposals about the further nuclear weapons stockpiles limitations and elimination.

On condition that the rest of the countries will follow the nuclear weapons non-proliferation and nuclear technologies non-transfer agreements the complete nuclear weapons stockpiles limitations will be the Russian leaders ultimate goal.

Active materials(plutonium and uranium)use and utilization is a part of the most important problem of nuclear weapons liquidation. Common efforts of the number of the countries are necessary for the development of special technologies and creation of necessary conditions for the materials processing and their peaceful use. To solve this problem some of the countries put forward the suggestions to help Russia.

The world must be saved from the most dangerous weapon ever created by the mankind only in cooperation with all the members of the international community in the direction of nuclear weapons stockpile reduction and limitations and atomic scientists potential consolidation.

FONDAZIONE PER LA PACE
E LA COOPERAZIONE
INTERNAZIONALE
"ALCIDE DE GASPERI"

S T E S
SCIENZIATI E TECNOLOGI
PER L'ETICA DELLO SVILUPPO

(8)

International Symposium
on
"CONVERSION OF NUCLEAR WARHEADS FOR PEACEFUL PURPOSES"

Palazzo Doria - Rome
June 15-17, 1992

Outlook of a Safe and Feasible Conversion Responsabilities of International Organizations

"Demilitarization: Future Potential for Worldwide Nuclear Energy"

by H. M. AGNEW

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DEMILITARIZATION, FUTURE POTENIAL FOR WORLDWIDE NUCLEAR ENERGY

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JUNE 15-17, 1992

The decision to make major reductions in the nuclear weapons stockpiles of the United States and Russia in addition to promising the potential of lessening tensions between these world powers could, if properly implemented, provide a long term bonanza for the environment and the world's population. It also will present some new challenges. There is no disputing that the most flexible and benign end use form of energy is electrical energy. Today the major fraction of electrical energy generated is by burning fossil fuels, primarily coal, oil, gas, and wood. All of these contribute carbon dioxide carbon monoxide, oxides of nitrogen, and in addition coal fired plants emit tons of lead, sulfur, mercury, uranium, and other pollutants worldwide. For the most part developing nations need electrical energy and many are fossil fuel poor. Clean and safe generation of electrical energy is what the whole world needs in the decades ahead.

The challenge presented by the potential dismantling of thousands of nuclear weapons is that of ensuring that the enriched uranium and plutonium contained in these weapons is not diverted to other nations who desire a nuclear weapons stockpile but have no fissile material. The main impediment today in acquiring a nuclear weapons capability is the acquisition of enriched uranium or plutonium in quantity. The knowledge required to make an effective fission weapon is readily available but to date the required fissile materials have been difficult and expensive to obtain.

A universal desire associated with the dismantling of nuclear weapons is to eventually destroy them. However, unlike conventional weapons the critical component of nuclear weapons, namely the fissile materials cannot simply be destroyed. The only way to remove these materials as tempting sources for new nuclear weapons, is to convert them into fuel for nuclear reactors whose sole purpose is the generation of electrical energy.

Russia and the former Soviet Republics are in need of hard currency in order to assist them in the conversion and development of their economy. Bonafide offers have been made to Russia by private concerns in the U.S., France, and Japan to acquire the surplus Russian fissile materials for conversion into nuclear reactor fuel. The enriched uranium would be diluted to less than twenty percent enrichment and the plutonium would be blended into a mixed oxide of uranium and plutonium and thereby would make them inattractive as a potential nuclear weapons materials. Facilities for the fabrication of large quantities of mixed oxide fuel are in place or under construction. In particular France, Germany and Russia have under construction large mixed oxide fuel fabrication plants.

MOX FABRICATION PLANTS OPERATING OR UNDER CONSTRUCTION

Country	Plant	Capacity (tons metal/year)	Status
Belgium	Belgonucleaire	35	Operating
France	Cardarache	15	Operating
Germany	Hanau	35	Operating
UK	BNFG/UKAEA	8	Operating
Japan	PFFF	5	Operating
France	Melox	120	Construction
Germany	Hanau	120	Construction
Japan	PFPF	40	Construction
Russia	Chelyabinsk-65	120+	Construction

Another option would be for a nuclear power to construct a reactor burning only weapons grade plutonium. It is estimated that a 1000 megawatt electrical reactor could consume, over its lifetime, 20 to 50 tons of weapons plutonium depending on whether its fuel was recycled or not.

Unfortunately to date no firm sales have been made or material transferred as a result of the various private acquisition initiatives. In addition there are also serious concerns with regard to the safety and economics associated with nuclear power in many nations. These concerns will persist until drastic changes are made in the design of the next generation of nuclear power reactors. Without these changes it will be difficult to gain public confidence in the advantages of nuclear power systems and to provide a disposal mechanism for the materials made available from nuclear weapons dismantlement.

U.S. suppliers are bringing into being a line of reactors which will have increased safety margins. These reactors are less reliant on active engineered safety systems and are generally termed as being passively safe. These passive systems do require certain mechanical devices to operate correctly, however no action is required on the part of the operators. The designed safety is therefore dependent on mechanical devices and no incorrect action by the operators. Unfortuantely the major nuclear reactors accidents have occurred because the operators did something. They did not do nothing. I believe if we hope to have a chance of "destroying" the fissile material from the major nations stockpiles, we must bring into being a new generation of inherently safe reactors. Reactors can be designed which do not depend on mechanical devices for their safe operation and for which the safety is independent of <u>any</u> actions taken by the operators. These designs are technically feasible.

The inherently safe design dictates that the reactor be small by present commercial standards, around 150 megawatts electrical, however, for developed nations several such modules (from two to eight) compete favorable with coal fired plants today.

For developing nations small plants are ideal. Their present needs can adequately be covered by smaller plants and there is no need for extensive power grids to disperse the power such as would be required for 600 to 1000 megawatt plants. In addition, the inherent safety of the system doesn't require the same level of operator expertise and extensive infrastructure support as is required with todays nuclear plants. Another advantage of the inherently safe high temperature reactors is that they can be used for process heat as well as generating electricity and their inherent safety allows them to be located adjacent to industrial complexes with no needed evacuation zones or procedures. Two main reactors of this type have been under development. The helium cooled high temperature gas cooled reactor has been under development by Germany, the U.S., and Japan and the lead or lead bismuth cooled high temperature reactor being developed by Russia.

Another reason for developing inherently safe reactors is that in spite of our wishes, the whole world is not at peace. Current examples of conflict are occurring in Yugoslavia, Armenia, Somalia and Nigeria to name a few.

During the past decade, there has been concern worldwide with regard to Iraq's real objectives in its extensive nuclear-research program. More and more, it became apparent that Iraq's objective was to develop a nuclear weapons capability. An attack on its early facilities by Israel set Iraq back, but did not deter it in striving for its primary objective of becoming a nuclear-weapons power in the Middle East.

As a result of U.N. military action in the Persian Gulf, Iraq's weapons-production facilities have been destroyed. It is fortunate that Iraq did not have an operational nuclear-power plant. Had such an operating power plant been attacked and even if during the attack the reactor vessel and the secondary-containment vessel were not breached, an event not too dissimilar from the catastrophe at Chernobyl might have been ensued.

A tremendous amount of energy is produced in the fuel rods of a nuclear power reactor even for hours after the plant has been shut down. To prevent this energy from melting the fuel rods and causing what has been called a melt-down, existing lightwater reactors require a continuous flow of water to remove the heat (energy) from the fuel rods.

This water must circulate to remove the heat. The circulation is achieved by electrically driven pumps. An external source of electrical power is required to drive the pumps when the reactor is shut down and not generating electricity. Local power from other power plants or emergency on-site diesel generators are normally the source of this electrical power. In peacetime, these sources are adequate. However, the electrical and/or diesel power supply to all reactor stations is vulnerable in the event of a war or even modest guerrilla actions. A deliberate attack as was carried out in Iraq could easily interrupt such supply. Without the power to provide circulating water, the water would evaporate, the fuel rods would overheat, melt and react with steam and water within minutes.

A tremendous steam pressure in the reactor vessel would develop, which would vent to the secondary-containment vessel. Depending on the severity and speed of the energy buildup, it is conceivable that the secondary containment also would be breached and a Chernobyl-type accident would be repeated, causing a huge area of radioactive contamination.

These events could occur independent of the expertise of the operators or the excellence of the design and construction of a water-cooled reactor system.

The developing nations are in dire need of electrical energy. Without it, they will never develop. Most of them have no indigenous fossil-fuel sources. Many of them have been stripping their forests of wood to burn and are creating man-made deserts.

It was thought that nuclear power could in the future be an attractive option for these developing nations. However, if these nations - in addition to all their other problems - and the rest of the world have to worry about armed conflict on their territory, a legitimate question would be: "Is nuclear power really an option that we can risk in these areas?"

The answer, strange as it might seem, is yes, but not through deployment of present day water cooled reactor technology.

A recent shutdown from full power of a full-scale helium-cooled graphite reactor in Germany, with no external removal of heat, clearly demonstrated that an inherently safe nuclear-power reactor can be made. The whole shutdown sequence was presented on a NOVA program on the US Public Television Network.

Several unique design features provide this inherent safety, characteristic for helium-cooled or lead/lead alloy graphite moderated reactors. The fuel is refractory-clad and cannot melt at any temperature the system can achieve. The maximum temperature is determined by geometry, power and power density of the system, the large heat capacity inherent in the graphite moderator and ability of the system to conduct and radiate the heat to the surrounding environment.

The typical size of such a reactor system, about 400 megawatts thermal (150 megawatts electrical), is small enough to be factory-fabricated and certified, and to be sited below ground level.

Needing no external power to maintain integrity, in event of a hostile action, the safety of the public in the surrounding regions is assured. No other nuclear-reactor system has the inherent safety features of this system, known as the modular high-temperature gas-cooled reactor (MHTGR).

If nuclear power is ever to regain public confidence worldwide, it will have to be based on plants such as the modular high temperature gas-cooled reactor with inherent safety characteristics. No other system can meet its safety characteristics in peace or during local conflicts.

Hopefully with the dismantling of thousands of nuclear warheads, tons of enriched uranium and plutonium will be available to be converted into fuel for the next generation of inherently safe reactors to provide a clean safe source of electrical energy for the decades ahead. At the same time if the private sector is allowed to purchase the uranium and plutonium from Russia and the United States, both governments will benefit by an infusion of much needed capital from the private sector. For the U.S. it will help lower our national debt and for Russia provide much needed hard currency which will assist them in achieving their new economic base objectives.

At present, when nuclear suppliers sell a reactor to a nation, they also sell the nuclear fuel and leave it up to the purchaser to solve the problem of disposing of the spent fuel elements which contain plutonium, residual uranium-235, and fission products, under safeguards but with no specified sanctions for non-conformance.

A reactor without fuel poses no threat. If the supplier nation simply leased fuel on the basis of its energy content - instead of selling it - to the nation purchasing the reactor, and if the fuel then reverted to the supplier after it had served its purpose, there would be no problem about what the receiving nation might do with the residual plutonium.

The question of recycle need never arise, as far as the lessor is concerned, since the client nation has contracted for energy only, not the ownership of the fuel elements. The plutonium, fission products, and so forth would belong to the supplier nation. And that nation, probably an established nuclear power, would decide what was to be done with the spent fuel. There would be no need for the leasing nations even to consider having a recycling plant because they would own no fuel to recycle.

If this were to be our future policy, and if the nuclear powers would simply all agree never to sell the fuel but simply to lease it at a fee based upon the fuel's capacity to deliver a certain amount of thermal energy, a great deal of world concern could be alleviated. It would also make much simpler the concept of international regional nuclear recycling and waste-disposal centers. Leasing is a common practice in the West; the larger computer suppliers and copy machine manufacturers have been doing it for years.

Such a procedure will not prevent major industrial nations from developing a nuclear industry or from developing nuclear explosives, but it will prevent the government of an underdeveloped or small nation, which has a legitimate need for nuclear power, from being tempted to develop nuclear explosives. It would also clear the air with regard to a nation's eventual intentions. If a government refuses to accept a nuclear power contract wherein the fuel is provided only through a lease agreement, with its final disposition to be determined by the supplier, then it clearly must have more in mind than providing clean, cheap energy to benefit its people. Leasing had been the practice of the Soviet Union with respect to the nations it supplied.

The developing countries will argue that this is discrimination and supplier cartel. They're right. But what are the purposes and effects of the discrimination? OPEC, for example, is a discriminatory cartel to raise prices and keep them as high as the traffic will bear. Mandatory leasing by suppliers, however, confers a financial benefit on recipient states, which will not have to capitalize fuel inentory. This is in return for isolating supply from the uncertainties of nuclear proliferation events such as India's explosion.

Leasing also will guarantee long-term fuel supplies because the supplier nations will have to do something to recoup residual values in spent fuels. They will have to reprocess, when the overall economics so dictate, and this can be done most economically on an international basis. The suppliers, as fuel bankers, can't afford to sit on wasting assets - that is, plutonium and uranium. Plutonium will be available for recycle, but only when it makes economic sense; and when it does there will be firm controls on "the plutonium economy" because the fuel will be available only on lease terms.

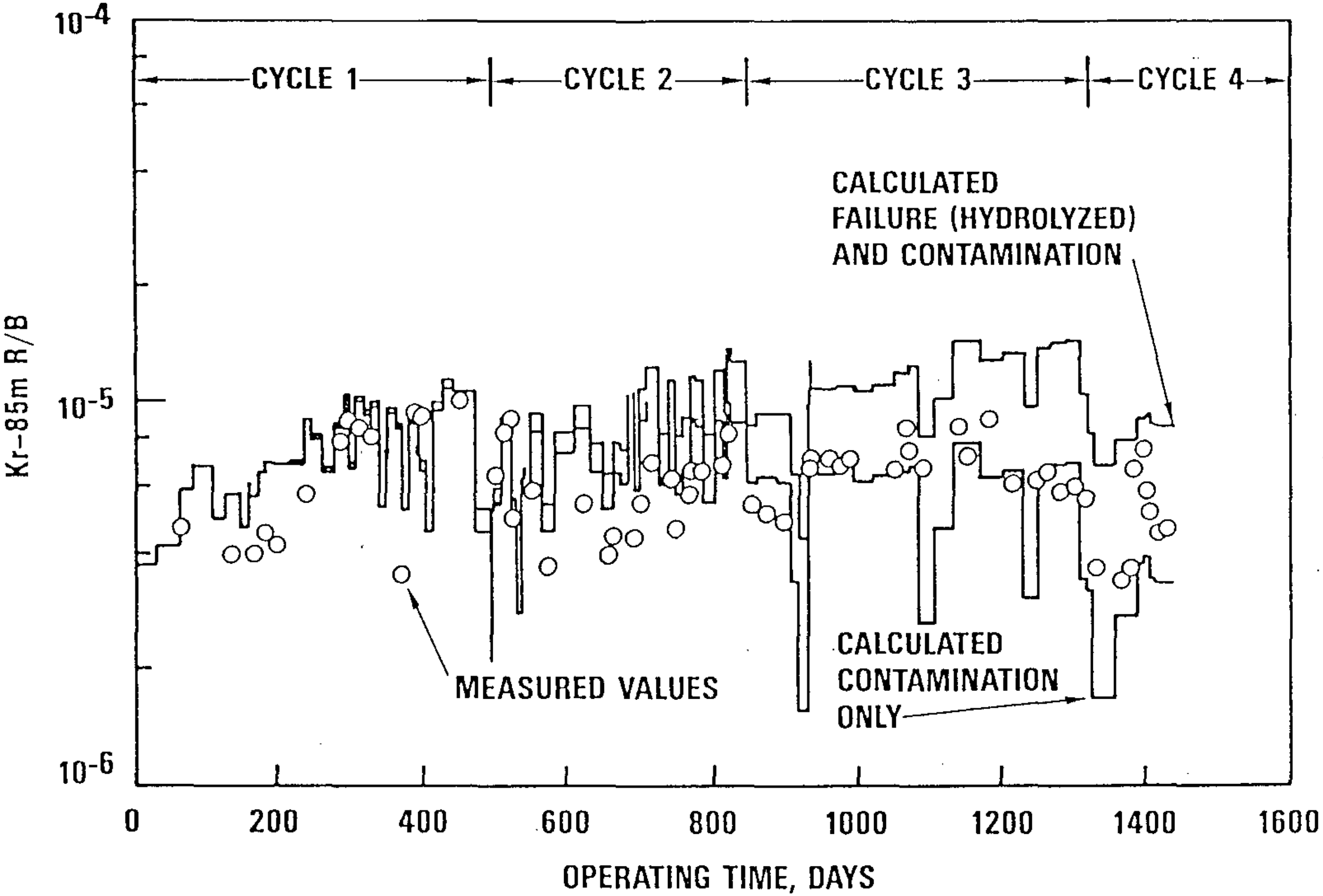
Such a policy finally leads to an international "fuel bank," controlled by suppliers in whom ownership of special nuclear material is vested. The retained property rights should provide a much firmer basis in international law for safeguards inspection and, if necessary, action by force to recover property in the event of misuse.

It probably also makes sense to lease to utilities and other users within the United States. This procedure can help the utilities financially, and they need it right now. But it also provides a much firmer foundation for domestic safeguards. Diversion in this country is really a hostile act against the government, with a presumption of threat to national security. It should not be regarded as simply an attempt to steal property, where redress under most applicable state laws is limited to the value of the property.

The fundamental reason the "Private Ownership Act" was passed in 1964 was to get the U.S. government out of the role of banker. The earliest international agreements for cooperation were on a government-to-government lease, and then only for research purposes. When power reactor agreements began to be negotiated, foreign governments were obliged to retain title to transferred material for power reactors until private ownership was permitted in the United States.

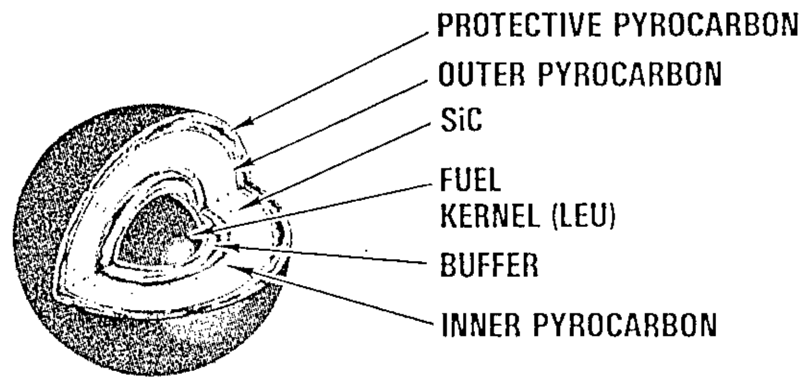
It's time to rethink these steps. We must address the need to establish an international nuclear fuel bank, where title is held by the participating supplier government's licensed agents and fuel is available through licensed private agents only on lease terms to all users. Treaty arrangements could then put real teeth in what steps suppliers could take if clients cheated or misused leased materials.

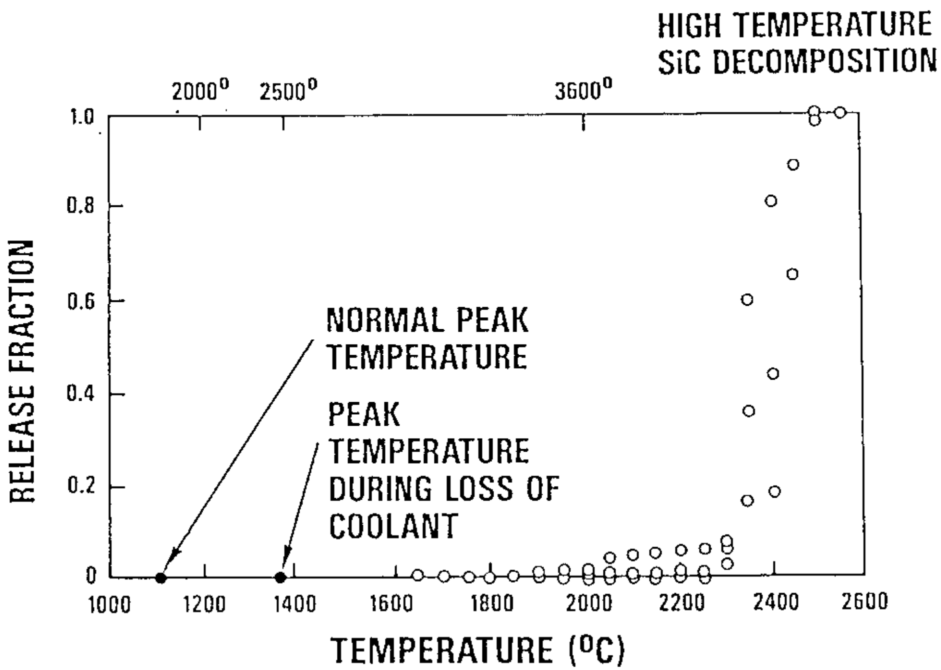
COMPARISON OF MEASURED Kr-85m RELEASE DATA AND PREDICTIONS FOR FORT ST. VRAIN



CERAMIC COATED FUEL PARTICLES RETAIN RADIONUCLIDES UNDER NORMAL AND SEVERE ACCIDENT CONDITIONS

CERAMIC TRISO-COATED FUEL PARTICLE





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Economic Aspects of Conversion

"Evaluation of Utilization of Nuclear Materials From Disarmament"

by E. LAZZARINI

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A FEW CONSIDERATIONS ON THE UTILIZATION OF NUCLEAR MATERIALS FROM DISARMANT.

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Although I am a scientist and not a technologist, nevertheless the organizing committee asked me to summarize some technogical considerations advanced during the preparation of this meeting. Therefore my talk is to be intended as a short qualitative summary of the technological problems posed by the recycling of nuclear weapons to peaceful uses.

First, let me say that in my opinion there are not any serious, that is un-resolved, scientific or technological problems concerning the feasibility of nuclear war-heads conversion into nuclear fuel for the production of electro-nuclear energy.

By contrast real problems are posed by the economic impact of this conversion on the uranium market and related industrial enterprises, like separation plants of uranium isotopes or plutonium recovery from reprocessing plants.

As matter of fact, the nuclear material inventory of nuclear weapons to be recycled, corresponds, more or less, to the total electric energy production during the year 1988, fifteen percent of which being of the nuclear type. This means that war-heads constitute, more or less, the nuclear fuel inventory required by the electro-nuclear power stations for six operational years.

By contrast not only is the uranium market now depressed, but the uranium enrichment plants themselves are also over-dimensioned with respect to the present demand of civil market. Actually the capacity of uranium enrichment plants now installed is 40 milions SWU, but only 75% of this capacity is used. It is worth noting, however, that some diffusion plants should shortly go out of operation since obsolete and no longer competitive with respect to the modern plants based on gas centrifugation. Furthermore, projects based on LASER technology are under intensitive development, so that it is hoped that in few years more convenient and flexible plants may be ready.

In this sense the conversion of uranium war-heads to peaceful application may be interesting, and perhaps useful to wait for the more developed separation plants.

A second problem (this time of a politic nature) is posed by the recycling of plutonium war-heads because plutonium, unlike uranium, cannot be diluted with its inert isotopes, or with other elements suitable to prevent possible proliferation of nuclear weapons. Actually plutonium may be easily reconverted from peaceful-to military uses by chemical means.

As the argument was discussed by other speakers, I would not (won't) deeper in this matter of summarizing some reasonable flow sheets for the treatment of uranium warheads.

Before being released on the civil market, in order to avoid possible nuclear weapon proliferation, the highly enriched uranium of war-heads (containing 93% of ^{235}U), must be diluted with less unriched uranium down to a safe concentration level.

Since civilian enterprises are at the moment licensed to treat nuclear fuel whose enrichment in ^{235}U is not greater than 5%, the uranium of war-heads should be diluted down to this level in military factories or in factories under military control.

Isotopic dilution may be performed with:

A) depleted uranium of the tails of previous separations (containing 0.25% of ^{235}U);

B) uranium coming from reprocessing of irradiated fuel containing ~ 0.6-0.7% of ^{235}U;

C) fresh uranium (containing 0.72% of ^{235}U);

D) or, finally, with slightly enriched uranium, e.g. 2% in ^{235}U.

Dilution with uranium of separation plants tails or reprocessed uranium should obviously increase the immediate crisis of uranium mining as well as that of the already over-dimensioned separation plants. The consequences for the future of electro-nuclear energy production may be enormous.

The use of natural uranium should have a minor impact on uranium mining, but it leaves unsolved the problem of uranium enrichment plants, so that dilution with slightly enriched uranium seems to be the best choice, although it delays the ultimate solution of nuclear weapon conversion to peaceful uses. In particular, dilution with 2% enriched uranium was suggested as an adequate compromise among the factors mentioned above.

By contrast it is worth noting that from 1 part of uranium of military grade one may obtain:

A) 34 parts of nuclear fuel at 3% if tails of uranium separation plants are used for dilution of military grade uranium;

B) 40 part of the same fuel in the event of dilution with natural uranium;

C) or 91 part, always of the same nuclear fuel if the dilution is made with uranium containing 2% of ^{235}U.

The price to be paid for saving uranium mining and separation plants in terms of increased war-head recycling time is quite evident (the time is doubled).

Finally it may be stressed that science and technology have nothing to do with the choice to be made, which may also be deeply influenced by political factors.

Looking at the chemical aspect of the problem the goal of the chemical treatment is the transformation of metallic uranium of war-heads into uranium oxide which is the most widely used chemical form of nuclear fuel.

Metallic uranium may at first be transformed into uranyl nitrate by nitric acid attack or in uranium hexafluoride by attack with BrF_3 leading to UF_6 and then in uranium ceramic oxide. Both reactions have been throughfully investigated so that the war-heads dissolution does not pose any particular problem or difficulty even in the event of uranium containing more than 90% of ^{235}U. Obviously precautions must be taken to prevent accumulation of the critical mass in the dissolver, but this problem has already been resolved by applying one of the following three methods or a combination of them.

1) use of subcritical geometry;
2) control of fissile material concentration;
3) addition of a soluble neutron absorber having suitable solubility in the solvent used for uranium attack.

Safe dissolver based on these methods are described in unclassified literature easily available. They may also be applied to the dissolution of pure ^{235}U. For example aqueous solutions containing in one litre up to 1.2 gatom (i.e. 280g) of U with 100% ^{235}U and 0.03 gatom (i.e.5.6g) of natural gadolinium are still subcritical, whatever the container volume and shape may be.

The choice of the type of uranium chemical attack (HNO_3 or BrF_3) dissolution may be effected in relation to the ^{235}U isotopic dilution adopted for the warhead uranium. If the military grade uranium has to be diluted with 2% enriched uranium, the attack with BrF_3 might be more appropriate. Indeed UF_6 may be safely shipped to uranium separation plants for the isotopic dilution in monel cylinders of suitable size to prevent the attainment of a critical mass.

The same may also be said for HNO_3 attack, i.e. the uranium nitrate of military grade may be delivered to uranium separation plant for the isotopic dilution down to 3% in ^{235}U. In both cases, the military installations should probably be supplied by suitable dissolvers.

A final consideration, again of political and economic taste: It is quite evident that there is an over-killing capacity in terms of nuclear weapons and that storage installations, maintainance, and security control of this over-dimensioned stock is not only militarily useless, but also expensive. Then the conversion of war-heads to peaceful applications is not only an ethycal choice, but also good business because of the money saved. The obvious conclusion is that the cost of weapon conversion to peaceful uses should be supported by military budgets using the money saved.

FONDAZIONE PER LA PACE
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S T E S

SCIENZIATI E TECNOLOGI
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10

International Symposium

on

"CONVERSION OF NUCLEAR WARHEADS FOR PEACEFUL PURPOSES"

Palazzo Doria - Rome
June 15-17, 1992

Economic Aspects of Conversion

"Technological and Economic Aspects of PU Utilization in Fission Reactors"

by K. UEMATSU

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THE TECHNOLOGICAL AND ECONOMIC ASPECTS OF PLUTONIUM UTILISATION IN FISSION REACTORS

by

Dr. Kunihiko UEMATSU
Director-General of the OECD Nuclear Energy Agency

I) Plutonium

(1) Plutonium is technically different from uranium in the nuclear fuel cycle from the dismantling stage to the fabrication of nuclear fuel.

Plutonium, normally produced in power reactor fuels ia mixture of isotopes. The percentage of Pu239, the dominant isotope, is around 50% and others are Pu236, Pu240, Pu241, and Pu242. However, in plutonium for military purposes the percentage of Pu239, which is fissile, is extremely high. That percentage is said to be more than 93~94% and the rest being almost all Pu240.

As for radiation, the half-life of Pu239 is 2.4x10E4 years and the half-life of Pu240 is 6.5x10E3 years, they also have much stronger radiation than that of U235. Plutonium must therefore be treated under sufficiently strict radiation protection and safety conditions, contrary to the case of uranium.

Plutonium also generates decay heat, a cooling system is therefore required for its storage or transportation. For example, assuming that the percentage of pu239 is 95% and the rest of plutonium is Pu240, the decay heat from 1 ton of plutonium is about 2000W. Therefore, in order to store a large amount of plutonium, a cooling system is called for with sufficient capability.

Plutonium produced from power reactor spent fuel includes more than 10% of Pu241, which decays into Americium241 during storage, and americium241 and decay product from Pu236 radiate gamma rays. Therefore, as storage time becomes longer, it becomes more difficult to deal with plutonium in the process of fabrication. In addition to that, americium241 produces its fissile value because americium easily absorbs neutrons. As for plutonium for military use, this is composed mainly from Pu239, and produces little americium, and the terms of storage hardly matter.

If we deal with plutonium in metallic form, the following problems could occur;

1) it is easy to reconvert such metallic plutonium for military purposes again;

2) it is unsafe to store metallic plutonium under ordinary atmospheric conditions for a long time because plutonium can easily be oxidized;

3) we have no experience in storing tens of tons of metallic plutonium.

For the following reasons, it is better to convert metallic plutonium into plutonium dioxide in order to store large amounts for a long time:

1) it is difficult to convert stored plutonium oxide directly for military use;

2) we would not have to face the problem of self-oxidation;

3) we have long experience in storing large amounts of plutonium dioxide: for example, Japan, Britain and France have experience in large amounts of plutonium oxide;

4) there is an international consensus on the method of storing plutonium dioxide: IPS (International Plutonium Storage), a concept which was studied by IAEA, in 1978-1980, after INFCE, should give us sifficient technical confidence.

(2) Next, I will discuss reactors for burning plutonium. A fast neutron reactor is adequate to burn plutonium. The existing fast breeder reactors may be used to burn plutonium if the breeder zone is replaced by the reflector. This is the least expensive way to provide a plutonium burner. There are several fast breeder reactors in operation or going into operation, such as Super-Phenix in France, PFR in Britain, Monju in Japan and BN-600 in the former Soviet Union. Therefore, we could say that the idea of using fast breeder reactors to burn "weapon" plutonium is just about established.

It is easy to calculate the approximate amount of plutonium that fast breeder reactors without breeder zones could burn annually. For example, the specifications of Monju are as follows; the thermal power of Monju is 714MWt, the electrical power is 280MWe, the average burnup is 80,000MWD/t, and the amount of initial loading plutonium is around 1.4t. Assuming that the breeder zone is replaced by the reflector, the amount of plutonium burned is around 210kg/y, and the amount of plutonium produced in the core region is 130kg/y. Therefore, the net amount of plutonium burned is around 80kg/y. This is just a rough estimate.

Using this calculation as a basis, we can estimate the potential for burning plutonium of FBR in the former Soviet Union. The thermal power of BN-600, that is 1470MWt, is around twice that of Monju, therefore the amount of plutonium burned might be a few times higher than that of Mouju, that is to say, roughly 200~300kg/y. As for BN-350, the thermal power is 1000MWt, one and a half times the power of Monju. Therefore, the amount of plutonium which could be burned by both BN-600 and BN-350 could be roughly estimated to be around several hundred kg/y. Dr. Verikhov said at the press conference in Japan that it would take 80 years to burn 100t of plutonium from dismantling by using two FBRs in the former Soviet Union: I suppose, however, that he might have mentioned that this was on the condition of not including the reprocessing of spent fuel from FBRs.

By only using existing FBRs, the amount of plutonium burned is limited. If plutonium needs to be burned up as soon as possible, it would be better to construct reactors specializing in burning plutonium. The Science and Technology Agency in Japan has advocated the construction of a fast reactor specializing in burning plutonium produced from dismantling of nuclear weapons, and the Power Reactor and Nuclear Fuel Development Corporation (Japan) is studying a design for such a reactor. This reactor should be designed so as to consume more plutonium annually than existing FBRs, and it should have different reactor core characteristics from those of existing FBRs. Considering demand and supply of plutonium, this type of reactor could be the model for burning plutonium from weapon heads. Because the specifications of this type of reactor have not been established, it could be the subject of future discussion.

II) The effect of plutonium on the market

Dr. Verikhov, Vice-President of the Russian Academy of Science, said at a press conference in Japan, "The amount of plutonium produced from disarmament of nuclear weapons will amount to approximately 100t.". The latest Brown Book, which is soon to be published by OECD/NEA, gives us the data on the demands of plutonium among the OECD countries, which is 3.7tPuf/y. A rough calculation of the amount of plutonium required during the 15 years from 1996 to 2010, according to the data in the Brown Book, gives the following:

Year	Demand of Pu	Reprocessing capacity
1995	6.1 tPuf/y	4196 tHM/y
2000	12.9	4896
2005	13.7	4895
2010	13.7	4895

Assuming that the demand and capacity in the years for which we do not have projections between 1996 and 2010 are in direct proportion, the total amount of the demand during these 15 years will be 186.3t. The amount of plutonium produced from nuclear weapons would therefore be equivalent to half the amount of the demand during this period. On the other hand, as for the reprocessing potential of OECD countries, this will amount to approximately 72 thousand tHM during these 15 years. The NEA report "Plutonium Fuel: An Assessment" gives us the data that PWR of 1000MWe uses 24t of enriched uranium fuel and produces 0.115t of plutonium per year. Using this data, we can calculate roughly the production of plutonium for this 15 year period, which is 345t Puf. If the availability factor of reprocessing plant is around 55%, the demand and supply will coincide. Therefore, it is foreseen that if the plutonium produced from dismantling is supplied to the market, it would become surplus. Therefore, we may need to construct plutonium burners specially designed for burning plutonium from warheads.

III) The plan to construct plutonium burners

In order to burn plutonium, three methods can be considered. They are: utilising the existing fast breeder reactors, burning in thermal neutron reactors (Pu-thermal utilization), and constructing new reactors specializing in burning plutonium. Each method has advantages and disadvantages. The following is an example of construction of a special plutonium burner.

(1) Site of construction

Plutonium burners should be built close to the borders between Western and Eastern European countries, or in the coastal region of the ex-USSR on the Sea of Japan. The advantages of these locations are as follows;

1) siting is considerably easier than in Western European countries,

2) if the reactors generate electricity, they will help the local districts which are short of electricity. It is also cold in these districts and the reactors can provide heat.

3) employment in Eastern European countries can be expected to be boosted by the construction of reactors. In addition, this project can help prevent scientists who were engaged in developing nuclear weapons from being drained by other countries.

4) Western European countries can, of course, share the information obtained through the construction and operation of the reactors, which can also be expected to benefit Western European countries from a constructional and operational point of view.

(2) When to start

It is said that nuclear warheads can only be dismantled at a rate of about 5000 per year. Even if the dismantling is started in 1993, it would be after 1995 that enough plutonium to start fuel fabrication (tens or hundred of tons of plutonium) would be obtained from dismantling. In this case, it should be after 1998~99 that this plutonium would be turned into fuel assemblies and enough assemblies would be obtained to be loaded to a reactor. If the construction of a reactor is agreed in 1994, it could be finished around 2000, and then reactor and fuel availability would coincide. Therefore, the earliest time we could start burning plutonium would be the beginning of the next century.

(3) The size

The sizes of the existing fast breeder reactors are as follows; JOYO(Japan):100MWt, FFTF(US):400MWt, Phenix(France):570MWt(250MWe), PFR(UK):600MWt(270MWe), MONJU(Japan):700MWt(280MWe), Super-Phenix(France):3800MWt(1200MWe), and so forth.

Because plutonium burners do not mainly aim to generate electricity, they are not required to be of such a large size as Super-Phenix. They would preferably be larger than MONJU and would be built utilising our experience of existing rectors. Therefore, the desirable size of a plutonium burner should be around 1500MWt(60MWe). This size of reactor requires around 3 tons of plutonium for initial loading and will burn 1 ton of plutonium per year if designed effectively.

(4) Other merits

The primary purpose of the construction of plutonium burners is to contribute to world peace by means of burning plutonium from nuclear warheads. In addition to that, we expect various side effects, such as a boost in employment if plutonium burner are constructed in Eastern European countries, including the former Soviet Union. These effects are put into the attached table. The numbers in the table are the numbers of employees engaged directly in the construction or operation of the nuclear facilities. In addition to that, the number of workers would amount to around the same number as the employees hired directly by the nuclear industries. It is therefore expected that this project would contribute to the creation of employment for a long time.

In addition to that, it can be expected that other industries using energy, electricity or heat, would be created around the reactor site. The employment created by such industries could be large.

IV) It is important to initiate discussion on how to burn plutonium from nuclear warheads.

PROCESS	ADVANTAGES	EMPLOYMENT IN EASTERN EUROPEAN COUNTRIES
1. Designing plutonium burners		
Reactors need to be designed, and it is important to organise design teams in E. European countries. W. European countries should organise general design teams and Western engineers would take part in the E. European team.	The idea of safety designing from W. European countries can be transferred to E. European countries through joint design. It could also be expected that the idea of safety would be reflected in the maintenance of reactors under operation.	Long-term employment of around 10.000 people
2. Conversion of plutonium		
Conversion of plutonium from metallic form into oxide should be done in E. European countries.	It could be expected that technology concerning safety management and waste disposal would be transferred to E. European countries.	Around 100
3. Storage		
It would be necessary to build storage facilities and a joint design team would be required. After operation had begun, safeguards and radiation protection would be required.	The idea of safety management of W. European countries could be transferred through construction and operation of the facility.	Around 100

PROCESS	ADVANTAGES	EMPLOYMENT IN EASTERN EUROPEAN COUNTRIES
4. Transportation and Production		
This process is mainly carried out by W. European countries, only a small amount of work is done by E. European countries.	The technology of safe transportation could be transferred.	-
5. Nuclear Reactors		
Construction	It could be expected that the technology concerning safe building and quality control would be transferred.	A large number of people.
Operation	These technologies could be reflected in other reactors in E. European countries.	Around 300 people
	The technology con-concerning safety controls, radiation protection, waste disposal and management in emergency could be transferred to E. European countries.	

COMMENTS ON "THE DILUTION PROCESS OF URANIUM FROM NUCLEAR WARHEADS"

Session II

The technical aspects of the transformation of highly enriched uranium into fuel

by

Dr. Kunihiki UEMATSU
Director-General of the OECD Nuclear Energy Agency

As for highly enriched uranium produced from the dismantling of nuclear weapons, it is not as difficult as plutonium to convert and make into fuel. In order to convert highly enriched uranium into reactor fuel first of all it should be diluted in order to be of an adequate enrichment by being mixed with natural uranium or depleted uranium.* It should then be converted into UO2 or UF6 to be stored, finally converted into UO2, and transformed into fuel. Following are three possible methods for this process, which differ from each other in the method of dilution.

1) Convert natural uranium or depleted uranium as U3O8 into metallic form and mix with highly enriched uranium by melting and then convert into UO2. The problem with this method is that it would be very difficult to deoxidize a large amount of natural or depleted uranium into metallic form as required in the dilution process by using existing facilities, and it would also be very expensive.

2) Dissolve highly enriched uranium and natural or depleted uranium in nitric acid, mix them, and finally convert into UO2. The advantage of this process is the possibility of utilising existing facilities to dissolve a great deal of natural or depleted uranium. On the other hand, the disadvantage is that in the process of dilution of highly enriched uranium a great deal of nitric acid is necessary in order to keep criticality control, which would require a facility capable of dealing with a large amount of nitric acid and with strict criticality control.

3) Convert both highly enriched uranium and natural or depleted uranium into UF6, and mix them in gas form. The advantage of this method is that existing facilities can be utilised for the process of conversion of uranium into UF6. The disadvantage of this method is that it would be necessary to dissolve metallic uranium in nitric acid before converting it into UF6 as it could be an uncontrollable process to combine metallic uranium directly with fluorine. In this case, the same problem as the method described in 2) above, would arise, that is, the necessity of keeping criticality control during the process of dissolving highly enriched uranium in nitric acid.

The processes described above are quite simple, and it is probable that some of them could be carried out in existing facilities. The cost of these processes would, therefore, not pose great problems.

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* If we dilute 500t of highly enriched uranium into 5% enriched uranium, we need around 100t of natural or depleted uranium.

COMMENTS ON "WEAPON GRADE URANIUM AND THE NUCLEAR FUEL MARKET"

Session III

Economic aspects of supply of highly enriched uranium to the uranium market

by

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Director-General of the OECD Nuclear Energy Agency

I would like to make a comment on demand and supply of uranium, according to data in the Red Book, published in 1990 by OECD/NEA. The Red Book gives forecasts regarding demand and production capabilities for uranium until the year 2005: these are as follows.

Production capability supported by low-cost resource up to $80/kgU would be a little more than 40000tU/y, sufficient enough to meet demand until the year 2000. After 2000, demand will begin to surpass production capability and in 2005, the gap between demand and production capabilities will become larger. However, production capability supported by additional higher-cost resources, up to $130/kgU, could be boosted to around 60000tU/y, and therefore no serious production shortfall from low and high cost resources is expected. Nevertheless, it should be recognised that further low-cost resources could be available within this time-frame, as a result of technical developments and policy changes in certain countries. To summarise, through to the mid 1990s, excess inventories are expected to be drawn down and production will remain below capability. Towards the end of the century, it is expected that supply and demand will be more in balance with the need for new production to be brought on-stream to meet the increasing demand (see graphs).

The above forecast is based on data which does not include the USSR and China, data on these countries not having been disclosed. According to the information obtained by the investigation done by OECD/NEA/NDD last year, the maximum capability for uranium production in the former Soviet Union is around 16,500 tU/y and at present around 12,000tU is supposedly produced per year. According to other information, the domestic demand in the former Soviet Union is approximately 7,000tU/y. If this is true, the excess amount of uranium would be exported. It is, therefore, quite difficult to estimate the amount of uranium that would be available from the former Soviet Union from now on because the Soviet Union controlled production by controlling the amount of uranium stored under the planned economy up to last year. However, whatever the amount of uranium made available to the Western market by the former Soviet Union this will be in excess of demand.

As mentioned above, the Red Book projects that for uranium, demand the supply will be in balance until the end of this century. This forecast does not, of course, include the supply of uranium produced from dismantling nuclear weapons. Therefore if a great deal of uranium produced from dismantling is produced by the former Soviet Union, all of this would become further in excess of demand.

Next, I will discuss the value of highly enriched uranium, produced from dismantling, on the uranium market. Dr. Velikhov, the Vice-President of the Russian Academy of Science, said at the press conference in Japan that highly enriched uranium produced from dismantling would amount to more than 500ton. I have roughly estimated its value if all of it is used for conversion into reactor fuel: assuming that highly enriched uranium of more than 90% enrichment were converted into 4% enriched uranium, the amount of uranium produced by dilution would be:

500 ton U x (more than 90%/4%) = around 12,000 ton U

If we make this amount of 4% enriched uranium from natural uranium, the amount of natural uranium required is as follows;

12000 ton U x 7.436 = around 90,000 ton U
*7.436:is the amount of feed uranium required to produce 1kg of 4% enriched uranium, based on the conditions given by DOE.

The value of this amount of natural uranium, calculated by using $20.8/kgU (NUEXCO 1992.1; spot price), is around 1.9 billion dollars. I have roughly estimated the value of separative work by using the conditions given by DOE: the separating work for producing 1 kg of 4% enriched uranium is 6.554SWU, and therefore, the price of the separative work required for producing around 12000 ton of 4% enriched uranium is as follows:

12000 ton x 1000(kg/t) x 6.544 SWU/kgU x 117 $/SWU = 92.5 billion $
(The price of separative work is for long term contract.)

The value of uranium produced from dismantling is approximately equivalent to the sum of that of natural uranium plus separative work: around 100 billion dollars.

If such an amount of uranium were supplied to the uranium market without any planning, the market price would surely fall, and the market would be disturbed.

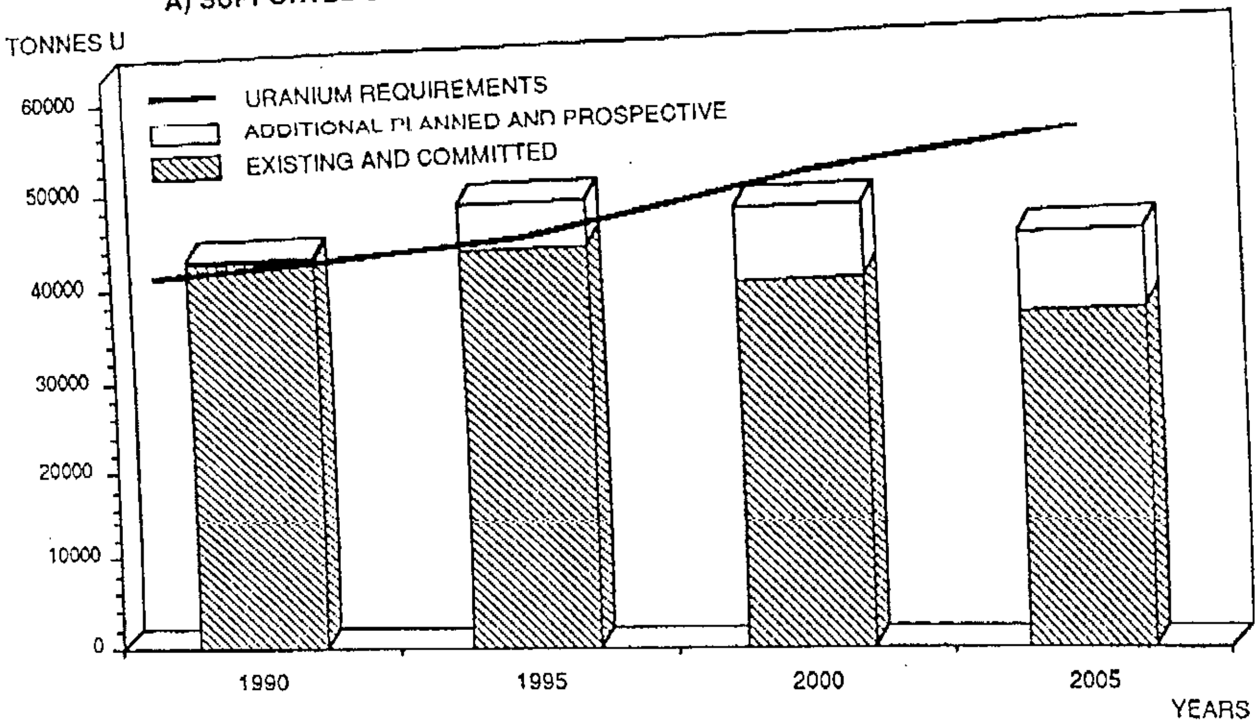
We should try to persuade the former Soviet Union not to supply a great deal of uranium immediately. However, the Republics of the former Soviet Union may need to sell uranium in order to help the recovery of their economies.

Measures should be taken to stabilise uranium prices which would benefit both Western and Eastern countries. One suggestion to a way of solving this problem is is that Western countries should, first of all, create a fund to assist the recovery of Eastern economies, and thereby assure the retention of such large quantities of uranium within the former Soviet Union in the stable form of low enriched uranium. After some time, the West would gradually withdraw fuel as needed. In this connection, Dr. Verikhov said at the press conference in Japan, that "Highly enriched uranium produced from dismantling is equivalent to three years' world production. If we sell it on the open market, the market would be seriously disturbed. We could start an international fund to stabilise the market."

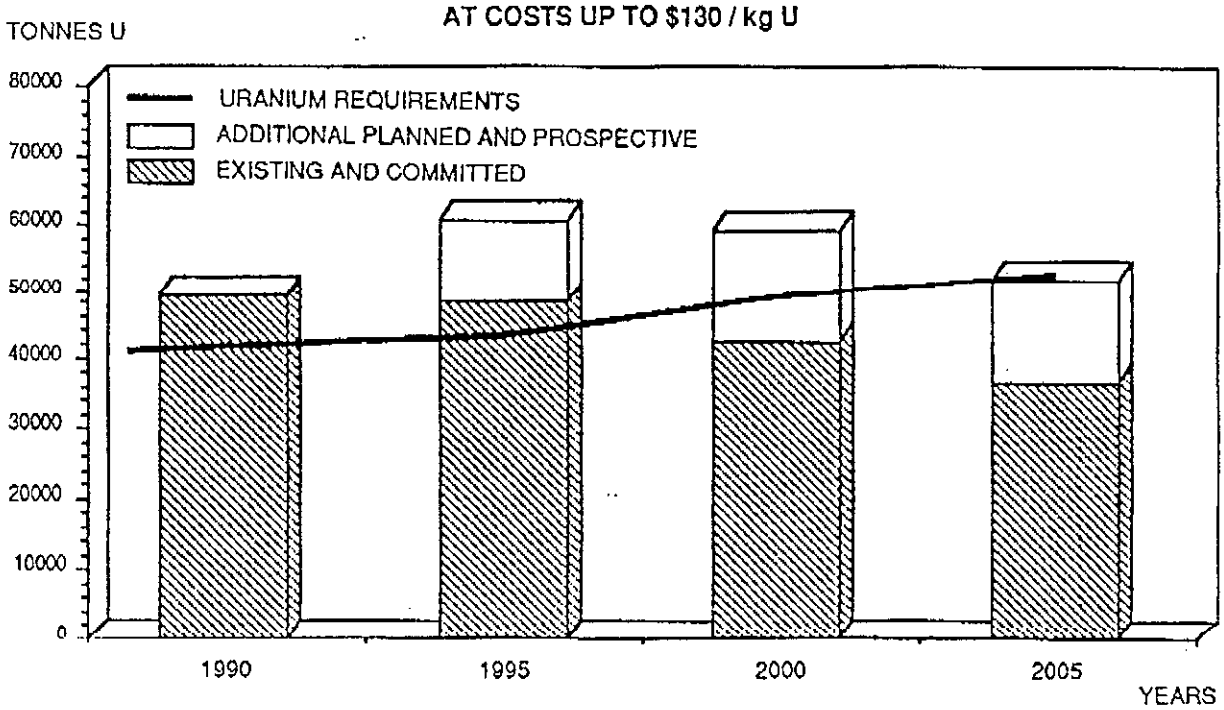
The amount of the "down payment" to be made by Western countries into the proposed fund could amount to a great deal of money. We would therefore need to give the matter our very serious consideration.

WOCA SHORT TERM ANNUAL URANIUM PRODUCTION CAPABILITY

A) SUPPORTED BY RESOURCES RECOVERABLE AT COSTS UP TO $80 / kg U



B) SUPPORTED BY RESOURCES RECOVERABLE AT COSTS UP TO $130 / kg U



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Economic Aspects of Conversion

"General Economic Evaluation of the Conversion of Nuclear Warheads into Electric Power"

by M. CUMO

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GENERAL ECONOMIC EVALUATION OF THE CONVERSION OF NUCLEAR WARHEADS INTO ELECTRIC POWER

An economic evaluation for the introduction in the market of the nuclear electricity of the fissile material coming from nuclear arsenals may be easlily deduced from the results obtained by the Working Group ANSALDO-ENEA-ENEL, on the basis of very realistic hypotheses on new constructions' trend with their related fuel cycle facilities. The six documents file allows a critical analysis of possible alternatives by means of parametric tables through which, depending on technological achievements progressively reached, on row materials market and on the related services, the cost is relatively easy to update economic estimates and consequently to determine the material fluxes on the market. The general terms of the problem are well known: the decommissioning of 30% of the present world nuclear arsenal and the consequent immission on the market of 300 tons of 93% enriched uranium in a time interval up to 2005. The parametric assett of the study allows to take easily into account the variations in the dismantled fissile material percentage and in the fuel demand from nuclear power plants (i.e. new orders delayed, first generation eastern power plants closed for safety reason, etc.). In the basic hypotheses the recovered, enriched uranium immission in the market does not cover the foreseen additional requests, reaching a little less than 50%; in that way a modest expansion, with respect to present values, is left to the natural uranium market. Similar considerations hold for the related separative work. All this is very important for the simple reason that the whole electro-nuclear industry, with its more than thirty years experience in power plants and related programs of life extension, cannot be heavily damaged by an occasional, not permanent immission of fuel within terms which are not regulated by the free market. This industry needs the essential services of the whole fuel cycle with continuity and regularity by means of pluri-annual contracts. In this sense the cited study seems very correctly performed, with all the necessary elasticity margins. For instance, we may recall the suggested strategy of producing for the market a fuel obtained with two operations: the first one enriching the natural uranium through existing plants up to an intermediate value, and the second one in a further enrichment by mixing it with "military" uranium till the requested value. Thus, a mixed strategy of enrichment-dilution would be realized, producing an enriched fuel at a lower cost for the saving of separative work units and the related electric energy. The availability of new enriched uranium at lower costs, due to disarmament programs, may so dilationate the investment programs for new enrichment plants, what is extremely interesting for the continuous progress in laser technologies. In its general terms, this study foresees an installed nuclear capacity of 400 GWe for the year 2005, whose 85% of light water reactors, with an increase in the number of nuclear reactor from the present 420 to 530 units. The yearly requirement of natural uranium, in the form of the oxide $U_3 0_8$, is envisaged to rise presque linearly from the 50.000 tons of the year 1990 to 70.000 tons in 2005; correspondingly, the world amount of separative work units rises from 30 milion to a little more than 40 millions.

The dismantling of the 30% of warheads in the fifteen years can supply the equivalent of 12.000 tons of uranium oxide enriched at 3.3%, which amonts to the 11% of the fuel necessary to feed all the light water reactors in this period.

The electric energy which would be theoretically available burning all the declared warheads amounts to 10.000 billion KWh, i.e. the total amount of electricity produced actually in one year in the world. The minimum time necessary to burn all the uranium of the warheads with all the present nuclear reactors exceeds the 6 years. The related economic value, at the present costs, is of the order of 50 billion dollars.

With these premises and with reference to the cited study, in order to deepen some particular aspects, let me express some personal impressions on the modalities and the phases of such an enterprise.
We have seen the opportunity of graduating the immission of the recovered fuel and, obviously, of controlling its price not to damage some essential services of the electro-nuclear industry irreversibly, as well as the opportunity of delaying the construction of new enrichment plants waiting for the industrial development of the much more interesting and econonomic laser technologies.

I think that the military apparatuses of the nuclear powers have no technological problems at all and have the full know how to transform the metallic uranium enriched at 93% to oxide enriched at 20% within their dedicated installations. The same military plants where this conversion and dilution takes place have no apparent difficulties to pile and stock the oxide, as well as to proceed to further dilution down to commercial values below the 5%, so to deliver it to civil fabrication plants, without any need to modify their licence regime with the reception of 20% enriched oxide (anyway this should be a minor problem). With the military safeguard on the fissile, the dilution should be performed only when really required and at the contingent exact values. The achieved experience on fuel irradiation brings gradually to higher burnups and longer charge periods, and consequently to higher and higher enrichments. For instance, new fuels are under development, with microspheres of uranium enriched up to 10%. Not to speak of particular applications, as for instance spatial applications of nuclear energy that will require highly enriched fuels ("clean" fuels, like U235, and not plutonium, before launching). So it is always advisable to dilute just before the real, specific application.

A global survey of the study evidences the huge economic gain of this enterprise and its very reduced (if not inexistent) technical difficulties.

Obviously the financial fluxes among the different parties must be well assessed before the start up. How much and to whom is the diluted uranium from the military arsenals paid? How is its price regulated not to alterate the market too much? Who is the surveillance Authority? These problems require international agreements not only for the market protection but also to guarantee pluri-annual agreements which saveguard the electro-nuclear societies, the IAEA procedures and inspections, etc. In this sense it is of primary importance the definition and the related powers of an international Authority whose mission has to last many years. Another important consideration on the suggested enterprise pertains to the echological benefits for the whole mankind. It is enough to consider that if the energetic equivalent of the burning of all the warheads corresponds to the world electricity production for one year (electricity which is mainly of fossile origin), the amount of carbon dioxide and of oxides of nitrogen and sulphur is really enormous. 10.000 billions KWh is the global amount of electricity; to generate 6.5 billion KWh a coal feeded power plant of 1000 MWe generates yearly six million tons of CO_2, 31.600 tons of SO_2, 2.500 tons of CO, 18.300 tons of NO_x and 2.400 tons of particulate and powders.
The corresponding amounts for an oil feeded power plant are $4.4 \cdot 10^6$ tons of CO_2, from 20.000 to 80.000 tons of SO_2, 2.200 tons of CO, 8.000 tons of NO_x and 130 tons of powders. The global echlogical gain is immediately evident.

Concluding, this enterprise is worth of the maximum attention from governments and international organisms, being well assessed that nuclear disarmament is much more important than the fossile fuel saving, as well as the reduction of the atmospheric pollution and the general economy gain.

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"CONVERSION OF NUCLEAR WARHEADS FOR PEACEFUL PURPOSES"

Palazzo Doria - Rome

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Economic Aspects of Conversion

"Utilization of Nuclear Materials Released as the Result of Nuclear Disarmament"

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1. INTRODUCTION

The withdrawal of some portion of fissionable materials (primarily Pu) from the military sphere is a practical task today. The impartment of properties that will make it impossible to use Pu for war purposes is readily achievable, e.g., through introduction of inert neutron absorbing components. However, in our opinion,"passive" methods are not suitable because they doom to infinite storage (actually disposal) of rather valuable and at the same time highly toxic and radiologically dangerous materials. Utilization of Pu in nuclear power is most expedient.

Russia has a developed infrastructure of nuclear fuel cycle that is a good basis for conversion of military Pu to energy producing one. There is some experience in using military Pu in reactors.

We match the problem discussed to the general strategy of nuclear power development and its present-day status. The higher rate conversion of Pu can be accomplished in fast reactors capable of "burning" Pu of essentially any isotopic composition. The latte fact is also important because at the radiochemical reprocessing plant significant amounts of energy producing Pu as purified dioxide have been accumulated generated in different reactors. However, in connection with a delay in the realization of an extensive programme of serial fast reactor construction and limit possibilities of using Pu in BN-350 and BN-600 now in operation w also consider thermal reactors as a large-scale way of Pu convers

2. DIRECTION OF RESEARCH AND ITS BASIC RESULTS

The key position in the problem of Pu conversion is occupied by a complex of work to produce U-Pu fuel. Investigations that were started by the SRIIM in 50^{ies} resulted in a creation of the first pilot bay in the middle of 60^{ies} and fabrication of the cores for the experimental reactors BR-5, IBR-2, IBR-30 and pilot fuel assemblies (FA) for the reactor BOR-60. The first experiments employed the method of mechanical blending individual oxides and pelletizing to produce fuel (table I). Beginning from 80^{ies} the work was concentrated on developing processes giving minimum dust of toxic materials and on improving the technological processes of the whole fuel cycle. Investigations simultaneously performed in several alternative directions, viz., sol-gel microsphere production through internal gelation in heavy organic liquids, granulation of co-precipitated U and Pu hydroxides using surface active agents, carbonate co-precipitation of hexavalent U and Pu, revealed both benefits and disadvantages of different methods and their applicability to purposeful goals as well as identification of directions for comprehensive studies of technologies under study [1]. All of them are favourably distinguished by insignificant dust formation and aerosol contamination of working zones; dust carry-over in case of ammonia granulate and microspheres being two orders less than for powders prepared by the carbonate process.

However, along with the ecology requirements the problems of workability, achievement of the specified fuel parameters, process stability and finally the validation of the fuel serviceability under reactor conditions are of paramount importance.

In 1986 the sol-gel process and beginning from 1988 the ammonia granulation technology were subjected to large-scale tests approaching the commercial level (the plants "Zhemchug" and "Grane table 1). This gave a considerable amount of valuable information. Despite the favourable results on the quality of pellets manufact from microspheres, significant disadvantages of the sol-gel process were revealed, viz., multistage, difficulties in maintaining constant physico-chemical properties of microspheres (rigid poorly compactible microspheres); multicomponent liquid waste that requires complex reprocessing methods to be used. On the contrary, due to its simplicity and favourable instrumentation the technology of granulation of co-precipitated U and Pu hydroxides in presence of high molecular surface active agents demonstrated its controllability and exclusive stability. Under optimized conditions the bulk density of as calcined granulate is about 1.5 g/cm^3; the flowability is 3.5 g/s; the fraction of particles less than 80 μ in size (at the main mass of granulate within 200-800 μ) does not exceed 2%. It is shown that all granulate lends itself to the normal process of a high-quality compaction without using binders. At the plant "Paket" a considerable amount of fuel pellets of the density 10.4-10.7 g/cm^3 were manufactured from that product. The process conditions are reduction of oxides in an argon-hydrogen environment for 1-2 h at 750-800°C, granule compaction at 3.5-4 t/cm^2, sintering of sleeves at 1500-1750°C for 1-2 h. The resultant pellets were used to fabricate fuel assemblies for testing in the reactors BN-650 and BN-600.

The priority was given to the method of ammonia granulation of mixed oxides over other technological processes. We assume this method to be comparable to others used abroad as to the workabili and the quality of fuel produced.

We assess positively the ALKEM technology of mixed oxide preparation by co-precipitation of carbonate compounds of hexavalent U and Pu [3,4]. The attractive properties of the method are feasibility of additional purification from impurities (americium included); significantly less shrinkage of pellets (as compared to those manufactured from granulated oxides). The latter circumstance is particularly important for U-Pu fuel used in thermal reactors.

Using the three methods discussed as well as the method of individual oxide mechanical blending semi-commercial plants have processed more than 400 kg U-Pu fuel and fabricated about 3000 fuel elements for BOR-60, BN-350, BN-600 testing.

None of the pelletized fuel elements lost its tightness at burn-up to 10 and even 20% h.a. (BOR-60, table 2). The data receive allowed RFP to be made for the design of a semi-commercial plant. Presently its first phase to produce fast reactor fuel is under construction. The work has been performed to about 50%. This will be a fully automated production with thorough gas and water clean- systems and the maximum elimination of radioactive element release to the environment. Design studies to construct a U-Pu fuel production line are under way as applied to thermal reactors.

Presently, a considerable experience has been gained in devel ment of mixed fuel technology and operation, particularly in Weste countries. At the same time additional investigations of some issu are required, in particular, provision of homogeneous fuel, influence of different factors on FGP releases, changes in fuel heat conductance and others.

The processing of military plutonium is likely to involve so difficulties related to initial operations: material conditioning for processing, treatment, dissolution of Pu-alloys, waste management at these stages. Primarily the issues must be studied related to potential fire and explosion safety, taking quantitati ly Pu compounds into solutions, creation of an adequately effici dissolution process; purification from accompanying components.

The problem of military Pu conversion for peaceful purposes certainly must be matched to the actual reactor base. Table 3 shows the feasible in principle versions of Pu utilization in nuclear reactors available and under construction (BN-800) in Russia. The data indicate that to-day one cannot expect high rates of conversion of military Pu. As far as the utilization of Pu in VVER reactors is concerned, it should be verified by additional investigations into the physics and technology of those reactors and new generation reactors VPBER-600, VVER-500. To resolve this problem one must also take account of the circumstance that energy producing Pu comes from NPP; its amounts (table 4) are commensurable to those of military Pu to be converted and will increase by 7-8 t annually.

Search for more efficient ways of conversion of military Pu for peaceful purposes would be more expedient in the framework of joint agreements between the states-holders of military materials.

Table I

PILOT AND SEMI-COMMERCIAL U-Pu FUEL PRODUCTION BAYS

Bays (production)	Location	Operation time	Purpose	Fuel composition and its production process	Type of Pu used	Capacity
1	2	3	4	5	6	7
Laboratory lines, bays	SRIIM Moscow	Early 50ies to present day	Preparation of experimental fuel specimens, fabrication of individual fuel elements	Delta-Pu alloys; PuO_2; $(U,Pu)O_2$ and oth. Different methods	Military	
Pilot bay	P.U."Mayak" Chelyabinsk	60ies-70ies	Manufacture of pellets and pilot fuel elements for fast research reactors	Pu alloys; PuO_2	Military	Total mass o: Pu used ~1 t
Pilot complex	SRIAR Dimitrovgrad	from 1985 to present day	U-Pu fuel production, fabrication of fuel elements and assemblies for fast reactor testing	$(U,Pu)O_2$; Electrochemical granulation and vibrocompaction of fuels	Military and energy producing	40-50 FAs/annum, fuel fabrication bay (350 kg Pu)
Semi-commercial plant "Zhemchug"	P.U."Mayak" Chelyabinsk	1986-1987	U-Pu fuel production for fast reactor testing	$(U,Pu)O_2$; sol-gel process	Military (from BN reactors)	35 kg Pu/annum (for 5 FAs)
Semi-commercial plant "Granat"	P.U."Mayak" Chelyabinsk	from 1988 to present day	U-Pu fuel production for fast reactor testing	$(U,Pu)O_2$; ammonia granulation of co-precipitated U and Pu compounds	Military	70-80 kg Pu/annum (for 10 FAs;
Semi-commercial plant "Paket"	P.U."Mayak" Chelyabinsk	from 1988 to present day	U and Pu dioxide pellet manufacture, fabrication of fuel elements for fast reactor testing	$(U,Pu)O_2$ produced by both mechanical stirring of individual U and Pu oxides and sol-gel process, ammonia granulation, carbonate	Military	10 FAs/annum (70-80 kg Pu

Cont. table I

1	2	3	4	5	6	7
Semi-commercial complex for mixed fuel production (1 line)	P.U."Mayak" Chelyabinsk	50% ready production	U-Pu fuel production, pellet manufacture, fuel element and assembly fabrication for use in commercial fast reactors	$(U,Pu)O_2$ produced by U and Pu co-precipitation	Energy producing and military	5-6 t Pu/annum
Semi-commercial complex for mixed fuel production (2 line)	P.U."Mayak" Chelyabinsk	Project developments	U-Pu fuel production; pellet manufacture, fuel element and assembly fabrication for use in VVER type reactors	$(U,Pu)O_2$ produced by U and Pu co-precipitation	Military and energy producing	5-15 t Pu/annum

Table II

RESEARCH AND COMMERCIAL REACTOR TESTS OF Pu-CONTAINING FUEL

Reactor	Time of testing	Fuel type and Production Process	Testing scale	Assessment of results
BR-2	1956	Pu metal	~ 20 kg Pu	Favourable
BR-5(BR-10)	from 1959	PuO_2	~ 150 kg Pu	Favourable
IBR-2	1965	PuO_2	~ 100 kg Pu	Favourable
IBR-30	from 1957	Pu metal	~ 100 kg Pu	Favourable
Crit. facility BFS (Ph.En.Inst.)	from 60ies	Pu metal	750 kg Pu	Favourable
BOR-60	from 1975	1.$(U,Pu)O_2$: electrochemical granulation and vibrocompaction of fuels	hyndreds kg Pu	Assessment is premature. There are events of fuel leakage; tests need to be continued
	from 1973	2. $(U,Pu)O_2$: mechanical stirring of individual oxides and pelletizing	tens kg Pu	Favourable results at burn-up < 20% h.a.
	from middle of 80ies	3. $(U,Pu)O_2$: co-precipitation by carbonate and ammonia processes and pelletizing	up to 10 kg Pu	Favourable results (burn-up of 10-12% h.a.)
BN-350	from 1980	1. $(U,Pu)O_2$: mechanical stirring of oxides and pelletizing	10 FAs	Favourable results in the whole testing cycle at burn-up of 5-9h.
	1990-1992	2. $(U,Pu)O_2$: ammonia co-precipitation, granulation and pelletizing	100 fuel elements	Favourable results (burn-up 10% h.a.)
BN-600	from 1990	$(U,Pu)O_2$: ammonia co-precipitation, granulation, pelletizing	8 FAs	No leakage was observed
MIR	from 1992	$(U,Pu)O_2$: co-precipitation by carbonate and ammonia processes and pelletizing (thermal reactor fuel containing 5% mass Pu)	2 fuel elements and 3 ampules	Initial stage of testing

Table III

VERSIONS OF Pu UTILIZATION IN NUCLEAR FUEL CYCLE

Reactor type	Pu utilization schedule	Pu inventory, t		
		Initial (per single reactor)	Annual make-up (per single reactor)	Anneal consumption in all indicated reactor cores
BN-350	Loading of whole core	~ 1.5	0.6	0.6
BN-600	50% loading of core*	1.1-1.2	0.6	0.6
BN-800	Loading of whole core	2.3	1.6	1.6
VVER-1000	1/3 loading of core	1.0	0.35	2.1**
	Loading of whole core	3.0	1.0	~ 6**

*On condition the reactor core is updated

**For VVER-1000 sited on the territory of Russia

Table IV

ACCUMULATION OF ENERGY PRODUCING Pu (BEGINNING OF 1992)

Spent fuel of reactors	Amount of Pu, t	Form of Pu
VVER-440	30	Pure dioxide received from fuel regeneration at radiochemical plant (in storage)
VVER-1000	7	Contained by spent FAs kept in storage facility
RBMK	25	Contained by spent FAs kept in storage facility
BN-350, BN-600	~ 4	Pure dioxide is extracted on fuel regeneration at radiochemical plant. Used to produce U-Pu fuel

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Theses of Paper

"DEVELOPMENT OF PRODUCTION PROCESSES FOR U-Pu FUEL ON MILITARY MATERIAL BASE TO BE USED IN NUCLEAR POWER"

to be presented at conference on

"Conversion of Nuclear Warheads for Peaceful Purposes"

M.Solonin

Removal of a portion of fissionable materials (primarily Pu) from military sphere becomes a practical task nowadays. Creation of Pu properties that make it impossible to use it for military purposes is readily achievable, e.g., through introduction of inert neutron absorbing components or "dilution" with energetic Pu. In our opinion, "passive" methods that condemn high toxicity radiologically dangerous materials to indefinite storage (actually disposal) are not tolerable; the most expedient way is to use Pu in nuclear power.

Russia has a developed infrastructure of nuclear fuel cycle; it is an adequate basis for conversion of military Pu to power. Moreover, experience has been gained in reactor utilization of military Pu.

The problem discussed is matched to the total strategy of nuclear power developments and its present status. The highest rates of Pu conversion can be provided in fast reactors, capable of "burning" Pu of any isotopic composition. The latter fact is also significant because at radiochemical reprocessing plant large amounts (~30 t) of energetic Pu in the form of purified dioxide have been accumulated. It is essential that burning-out both military and energetic Pu in fast reactors can be accomplished without accumulation of secondary Pu (due to inert breeding blankets).

However, due to the fact that large-scale construction of fast reactors has been haltered until 2000 and the possible usage of Pu in operating BN-350 and BN-600 is limited we also consider thermal reactors as a large-scale way of Pu conversion. Thermal reactors could accomodate as a less intensive one the concept of the first cycle of using military Pu followed by transfer of "secondary" Pu into fast reactors.

The key position in Pu conversion problem is occupied by a complex of work to produce (U-Pu) fuel. Investigations that were started in 50^{ies} allowed us to create in mid 60^{ies} the first pilot bay and fabricate cores for experimental reactors BR-5, IBR-2, IBR-30 and pilot fuel assemblies for BOR-60. The first experiments were based on mechanical stirring U and Pu dioxides. Beginning from 80^{ies} the accent is made on development of processes that would minimize toxic material dust formation and are amenable to full automation.

Simultaneous investigations in several alternative directions, viz., process of sol-gel microsphere preparation through internal gelation; granulation of metal hydroxides using surface active substances; carbonate co-precipitation of hexavalent Pu and U, revealed advantages and disadvantages of different methods and their applicability to different tasks. Using semi-commercial facilities at commercial plant more than 400 kg of U-Pu fuel have been handled and more than 2000 fuel elements have been fabricated for in-pile tests in BN-350 and BN-600. Not a single rod tested has lost its tightness at burn-up $< 10\%$ h.a., heat generation rate of 490 W/cm and cladding temperature $< 690°C$.

A semi-commercial plant has been designed and is now under construction; presently it is 50% ready. Its first line is designed to handle 5-6 t Pu per annum to produce fuel assemblies for fast reactors. Now the construction of the second line to produce U-Pu fuel for thermal reactors is under consideration.

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"CONVERSION OF NUCLEAR WARHEADS FOR PEACEFUL PURPOSES"

Palazzo Doria - Rome
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Technologies of conversion of Nuclear Materials

"Burning of Plutonium in Light Water Reactors (MOX Fuel Elements) Compared to other Treatment"

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Burning of Plutonium in Light Water Reactors (MOX Fuel Elements) compared to other treatment

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May 1992

1. Preliminary Remark

For legal (NPT) and political reasons we do not discuss nuclear weapons but only nuclear weapons material. The nuclear weapons material is supposed to show no characteristic shape in order to deny any clues to construction details.

2. Introduction

A large scale destruction of nuclear weapons is a difficult and expensive undertaking and will pose many problems. The generally preferred procedure to irreversibly destroy nuclear weapons consists of two steps, first of dismantling the nuclear weapons and second of neutralizing the nuclear weapons material. The first step can only be done by the disarming state itself - either alone or in cooperation with other nuclear weapons states (as fixed by the *Non Proliferation Treaty* (NPT)). The second step of neutralizing the nuclear weapons material in order to prevent any future military use can be done in cooperation with all nations which have a highly developed peaceful nuclear industry. This second step is the reason for discussing the German capacity of fabrication of fuel elements and the German experience in using such fuel elements in power reactors.

Let me pass a remark to the political situation of nuclear industry in Germany. There is very low acceptance of nuclear power by a lot of people. The consequence is that several political leaders try to stop all nuclear power plants and all nuclear fabrication plants. They do it by laws and orders and as a consequence there are huge safety measures which are very expensive. Another expensive effect are juridical delays.

3. Nuclear Material

Nuclear Fissile Material

We assume fissionable weapons material of about 1000 t weapon uranium and about 100 t weapon plutonium.

Radioactive elements with high mass (more than 200 amu) are mainly alpha-emitter. Therefore they are dangerous if incorporated but otherwise not because of a rather low radioactivity (corresponding to a long half-life) and a short range of alpha particles in shielding material (a sheet of paper would be enough). Plutonium is especially radiotoxic because after incorporation it is absorbed at the surface of human bones. So Plutonium should not be powdered or sprayed free in air but transportation in containments or handling in glove boxes is possible.

Contrary to these properties of the actinides the radioactive fission products are highly active gamma emitters with comparatively short halflives..

Uranium

The composition of natural, low and highly enriched uranium is listed in table 2.

Table 1: Composition of natural, low and highly enriched uranium.

	natural	LEU[1]	HEU[2]
U-238	99.28 %	96 - 97 %	6 %
U-235	0.711 %	3 - 4 %	94 %
U-234	0.0001 %		

[1] LEU = Low Enriched Uranium (3 - 4 % U-235) [2] HEU = Highly Enriched Uranium (94% U-235)

The Uranium production in the whole world is about 30000 t per year (0.711% enriched) which corresponds to 230 t HEU. This number has to be compared to about 1000 t HEU from nuclear weapons.

Plutonium

Plutonium (Z=94) is not found in nature but only produced in nuclear plants e.g. nuclear reactors (see table 3 and fig.1).

As seen in Fig.1 the amount of higher plutonium isotopes (Pu-240, Pu-241, Pu-242) increases, relative to Pu-239, the longer the fuel is irradiated in the reactor. Weapon-grade plutonium normally has about 94% Pu-239, reactor plutonium contains 60 % Pu-239. 94% Pu-239 correspond to a burn-up of a few thousand MWd/t Heavy Metal (HM) whereas fuel elements with 60% Pu-239 have a burn-up of 34000 MWd/t HM.

Nuclear Non-Fissile Material

Beryllium

Beryllium serves as a reflector in nuclear weapons. It is a highly toxic metal and should be handled with caution. On the other hand, Beryllium oxid is an insulator with outstanding properties for microwave electronics.

Lithium

Lithium-6 is used to breed tritium during the explosion of a thermonuclear weapon. This is the reason why Irak has been charged with constructing a thermonuclear weapon after inspection teams had found some Lithium-6. On the other hand, Lithium has a lot of chemical applications. So there is no problem of getting rid of it.

Tritium

Tritium is a hydrogen isotope and is one essential part of fusion material (beside deuterium). It is expensive to produce and difficult to store. Since tritium is used only in small quantities (compared to other nuclear weapons materials) and has the extremely short half-life of 12.6 years, tritium destruction poses no technical difficulties. From a technical point of view, tritium may be dumped into the ocean or could be enclosed into melted glass and deposited e.g. in abandoned mines.

There is no problem to convert highly enriched uranium by mixing with depleted or natural uranium and to sell it as low enriched uranium on the international or national fuel market. The only difficulty is the descending of the international market price of uranium during the last years. It is now at about 8 $/lb U_3O_8 at the spot market whereas the price according to long term contracts is at about 25 $/lb U_3O_8. If there is spent about 1000 t of highly enriched uranium corresponding to about 30 000 t low enriched uranium to the spotmarket this will bring down the price further. The world´s uranium production is about 30 000 t natural uranium per year which corresponds to about 6000 t low enriched uranium. From the comparison of the amount of 30 000 t low enriched uranium to the annual produced uranium the influence of this uranium supply to the market is evident.

To convert nuclear plutonium weapons to peaceful and safe material is much more difficult than uranium weapons. There are five possibilities as displayed in table 2: underground fissioning of Plutonium, underground melting and depositing of plutonium by a nuclear explosion, final storage, burning in a light water reactor or burning in a fast reactor.

Table 2: Possibilities for conversion of nuclear weapons to peaceful and safe material

<table>
<tr><td colspan="6">Nuclear Weapons</td></tr>
<tr><td colspan="6">dismantling</td></tr>
<tr><td colspan="6">transport</td></tr>
<tr><td colspan="6">Plutonium (metal)</td></tr>
<tr><td colspan="6">transport</td></tr>
<tr><td colspan="2">underground explosion</td><td colspan="2">final storage</td><td colspan="2">transient storage</td></tr>
<tr><td rowspan="4">Pu fissioning</td><td rowspan="4">Pu melting</td><td rowspan="4">with spiking</td><td rowspan="4">with denaturing</td><td colspan="2">transport</td></tr>
<tr><td colspan="2">fuel fabrication</td></tr>
<tr><td colspan="2">transport</td></tr>
<tr><td>LWR burning</td><td>FBR burning</td></tr>
</table>

The following paper discusses this five ways of conversion keeping in mind that three aims should be met at the end:

1) The material is in a safe form or at a safe place so that neither an unauthorized state nor terrorists have the opportunity to use the material as nuclear weapons material with an effort less than from natural sources.

2) There is no environmental danger.

3) The valuable plutonium should return a maximum of profit.

With regard to this discussion the physical properties of weapon grade plutonium are listed first and a short representation of german means for transportation of radioactive material is given.

4. Transport

As table 1 shows there is probably a lot of transportation necessary between the different processing stages provided there is no big nuclear center.

In Germany unirradiated fuel is transported in a stainless steel container with maximum 4,5 kg PuO_2. The safety car for this transport has a price of 1 - 3 millions of DM.

The CASTOR-Container for irradiated fuel elements is a cooling, shielded device which fulfills the international conditions for transport containers

falling from a height of 9m
falling from a height of 1,2m onto a thorn
30 minutes fire at 800 °C
8 hours under water

without any release of radioactivity. The price is between 1 and 2 millions of DM. The whole weight is 16 t and therefore the transport must be done by a flat-bed car or by railroad.

5. Underground Explosion

Underground explosion of all nuclear weapons is a non realistic expense. Underground explosion of one or a few weapons in order to melt the plutonium into the rock is possible but expensive. Furthermore it may be washed into the ground water and may lead to an environmental pollution.

6. Storage

Plutonium is a low radioactive material. If stored without further treatment there is the opportunity to fetch back the plutonium from the storage.

To denature the weapons plutonium with single isotopes e.g. Pu-238 is very expensive because production of single plutonium isotopes has to be done in an accelerator. To denature the weapons plutonium with reactor plutonium is possible but also expensive. One has to spent reprocessed plutonium which otherwise could serve as reactor fuel.

Spiking of the weapons plutonium with e.g. Co-60 in order to make the handling difficult is a means for a rather short time because the spiking material has a comparatively short half life.

7. Light Water Reactor Fuel

Figure 2 shows a reactor fuel cycle already modified to absorb weapon-grade heavy metal.

The following discussion is based on a 1300 MWe nuclear pressure water reactor as example. (This was the most frequently constructed power reactor in Germany's latest reactor construction period.) The fuel is uranium dioxide (UO_2) enriched to 3 or 4% U-235. It is fabricated as powder, compacted and sintered as pellets. Zircalloy or stainless steel rods are filled with these pellets and then welded at the ends. One fuel rod contains about 2.26 kg heavy metal (in this case uranium). 16*16 rods (236 fuel rods and 20 absorber rods) are assembled to one fuel element which contains about 533 kg heavy metal. 193 fuel elements are contained in the reactor.

The modification of the heavy metal content during irradiation is shown in table 3.

One third of the reactor fuel elements are replaced per year. Up to 450 t heavy metal per year is needed in Germany as new reactor fuel.

Uranium as Reactor Fuel

95% of the German reactor fuel is uranium but it will be partially substituted by reprocessed plutonium down to a level of 70 to 80 % in the middle of the 90s.

A centrifuge enrichment plant for uranium at Gronau/Germany has a capacity of about 650 t HM/year now and 1700 t HM/year during the 90s. The fuel elements are fabricated in Germany in two reactor fuel fabrication plants (Lingen, 400 t HM/year, and Hanau, 750 t HM/year).(Deutsches Atomforum,1991)

Conversion

As shown in Fig.2 Highly Enriched Uranium (HEU) metal must be converted to Uraniumhexafluoride (UF_6), mixed with natural or depleted UF_6 and can then be fed into the reactor fuel cycle.This could be done in Germany at Gronau. After mixing with natural or depleted UF_6 to a 3 or 4 % level, the Uranium is denatured and not any longer usable as weapons material.

CIS has about one tenth of the world's nuclear reactor power but more than this part of the world's fuel production capacity. For example Germany imported 114 t low enriched uranium from USSR in 1990. So mixing of the HEU with natural uranium may be done in the CIS.

The storage of low enriched uranium causes no particular safety problems neither from the proliferation nor from the radiation protection point of view. Contrary to spent fuel elements with a dose rate between 100 and 1000 Sv/h for a person standing nearby, a fresh fuel element imposes a gamma dose rate of a few µSv/h and about the same dose rate from spontaneous fission neutrons. (The dose rate from neutrons has not been calculated up to now because it has been not considered important.)

Burning

After dilution to a 3.5 % level, the 1000 t HEU will result in 27000 t of reactor fuel. Provided a burn up of 36000 MWd/t this will result in an energy output of 9.7E8 MWd or 2650 GWy. The installed power in nuclear reactors is round about 10 GW in Great Britain, 10 GW in Sweden, 20 GW in Germany, 30 GW in CIS, 50 GW in France, 100 GW in USA and 300 GW all over the world. So,to burn up all the CIS HEU needs at least ten years no matter which countries participate.

Plutonium as Reactor Fuel (MOX)

Germany has also a long tradition of working with reactor fuel.

There was a test reprocessing plant, WAK in KfK Karlsruhe, which has been operated from 1971 to 1991. A commercial reprocessing plant at Gorleben was stopped for political reasons and another one at Wackersdorf for political and economical reasons. Today there are long term contracts with La Hague/France for reprocessing the german spent fuel elements.

In 1920 DEGUSSA Company fabricated incandescent mantles out of Thorium and used Uranium for enamel colours. Later in WORLD WAR II Degussa supplied fuel for the Heisenberg reactor based on natural uranium at Haigerloch. This reactor got never critical because there was not enough carbon for moderating the neutrons. In 1963 ALKEM was founded as mixed oxide (MOX) fuel company where mixed means uranium and plutonium oxide mixing. Later on fusion with Siemens to Siemens Brennelementewerk (which means Siemens fuel element plant). Now there are about 2000 employees at Siemens Brennelementewerk.

The capacity of the Siemens Brennelementewerk Hanau is displayed in table 4.

Table 4: Capacity of Siemens Brennelementewerk Hanau.(Deutsches Atomforum, 1991)

	Uranium Section	MOX Section
Heavy Metal [t/year]	750	30 - 40 (120 from 1995)
U-238 [t/year]	725	
U-235 [t/year]	25	
Pu-239 [t/year]		1.2 - 1.6 (~5 from 1995)

Plutonium has a higher specific activity and accumulates in human bones. So at all fabrication stages of the fuel elements one has to use glove boxes with lowered air pressure or automated fabrication. This fact makes the (only) difference to UO_2-fuel element fabrication.

The UO_2 and PuO_2-powder will be mixed, compacted into pellets and sintered. Loading the pellets into rods is a special MOX problem because there should not be any contamination with plutonium and it has to be done within a glove box. Especially at the ends of the tubes near the welding areas, the rods must be decontaminated very carefully because after welding there is no way to remove any activity from the welding seam. After welding the rod can be handled outside the glove box and can be mounted into fuel elements.

The new MOX fabrication plant with 5 t Pu/year is nearly completed but the license procedure may take a long time. This plant is fully automated and has a threefold underpressure barrier.

There are three other countries that use or will use MOX fuel elements in their civil power reactors. France builds a MOX fabrication plant at Marcoule which will be accomplished in1992. In 1995 the capacity will be 100 t HM/year corresponding to 4 t plutonium. The plant in Cadarache has a capacity of 13 t HM/year (0.5 t plutonium).There is a further plant at Dessel/Belgium with a capacity of 30 t HM/year (1.2 t plutonium).Japan intends to use MOX fuel elements in two nuclear power reactors from the middle of the 90s. United Kingdom starts to build a MOX plant.

At present only Belgium, France and Germany have enough experience with MOX production facilities to start immediately projecting a new large facility whereever it is considered suitable.

Conversion

Whereas it is simple to mix HEU with natural or depleted uranium to a level well below 6% U-235-enrichment (which is a physical limit for a fast nuclear device), it is much more difficult to denature weapon-grade plutonium. Tests have shown that mixing it with Pu-238 is not practicable. The best utilization of weapon-grade plutonium is to produce MOX fuel elements and to burn the plutonium in a power reactor.

The plutonium metal from nuclear weapons has first to be converted to PuO_2 and can then be processed as described above. The German experience does not cover this process step.

The plutonium isotope 241 changes by ß-decay into Americium-241 with a half-life of 14.4 years. The content of Americium increases with storing-time as a function of the plutonium composition (the more Pu-241 the more Am-241). There is an Americium-limit for reprocessing plants because Am-241 is a strong alpha- and gamma-emitter. This well known fact is not so important in the case of weapon-grade plutonium because of its extremely low Pu-241 content. So there is no problem of storing time.

Burning

In Germany, there is a lot of experience with MOX fuel elements. The first time MOX fuel elements were used in Germany was in the nuclear reactor of Kahl in the sixties. Up to now about 50000 fuel rods have been fabricated and assembled in more than 400 fuel elements. There is experience with burn up from 2000 to 43000 MWd/t HM. No destruction of rods was found up to an axial power density of 550 W/cm (Dibbert,1988).

MOX elements essentially behave like UO_2 elements but there are some differences. The neutron spectrum is somewhat harder because of higher absorption cross sections of the plutonium isotopes. The efficiency of absorbers (Boron or control rods) is somewhat lower but acceptable from the point of view of the license authority. The criticality calculations for a compact storage of MOX fuel elements gives a somewhat higher k-inf. The surface dose rate is a little bit higher. (Faber et al.,1986).

There is a problem with the compostion of plutonium. All the reprocessing experience has been gained with reactor plutonium. But weapon-grade plutonium contains somewhat more Pu-239 (94% Pu-239, 7% Pu-240) than reactor plutonium (59% Pu-239, 23% Pu-240) or even than 1-cycle-reactor plutonium (81% Pu-239, 13% Pu-240) and the reactivity of the fuel elements is dependent of the plutonium composition (Faber et al.,1986). This is important for reactor operation and also for storage of fuel elements.

As far as the plutonium consumption is concerned, the number of MOX fuel elements in a power reactor is up to now limited to one third. Today in Germany not more than 150 t HM per year can be used as MOX fuel elements. This corresponds to 6 t plutonium.

8. Fast Breeder Reactor Fuel

Whereas the enrichment (or PuO_2 part) in the LWR is 3-4%, the fast breeder or fast converter reactor has 15-30% enrichment. From this point of view the FBR is more suited than a LWR to burn the plutonium. If there are fast breeders and if there is enough knowhow to run them it is possible to use the weapons plutonium as fuel. But anyway it is necessary to have a MOX fabrication plant.

9. Summary and Conclusion

Up to 1000 t HEU and 100 t weapon-grade plutonium have to be converted and burned in order to destroy it as nuclear weapons material. For HEU it may be sufficient to mix it with natural uranium down to an enrichment level of less than 6%. This dilution process is quick and requires only knowhow about fuel fabrication as available in many countries. After being mixed the HEU is denatured as nuclear weapons material and can be stored.

Plutonium is a more serious problem because weapon-grade plutonium is difficult to denature . The best way to get rid of it is to burn the plutonium in nuclear reactors as soon as possible. At present, only four nations (Germany, France, Belgium, Japan) are planning to use fuel elements with reprocessed plutonium in their civil reactors. Together they have a MOX fabrication capacity of 3.2 t Pu/year today and about 12 t Pu/year as of 1995. These numbers have to be compared to 100 t of weapon-grade plutonium in the CIS not to mention the fact that the plutonium from reprocessing plants has to be worked up,too. To build a new MOX fabrication plant needs approximately five years and 300 millions of $.

But first one has to build a high security transient storage for nuclear weapons, to dismantle them, to put the weapons plutonium also into a high security transient storage and after having built a MOX fabrication plant sell the MOX fuel elements. At this same time stop selling uranium fuel elements in order to fetch an adequate pricefor the MOX fuel elements.

High security storage means that there is no way to remove weapons or weapons material from this storage, neither by force nor clandestine. IAEA, EURATOM and several nuclear research centers as for instance ISPRA have developed very useful safeguard methods. Up to now it is possible to detect plutonium weapons by neutron radiation through a 2m concrete shield. Another tool for detecting nuclear weapons or nuclear weapons material by a high purity germanium gamma spectrometer.

Hopefully it is possible to prevent proliferation maybe with the assistance of IAEA.

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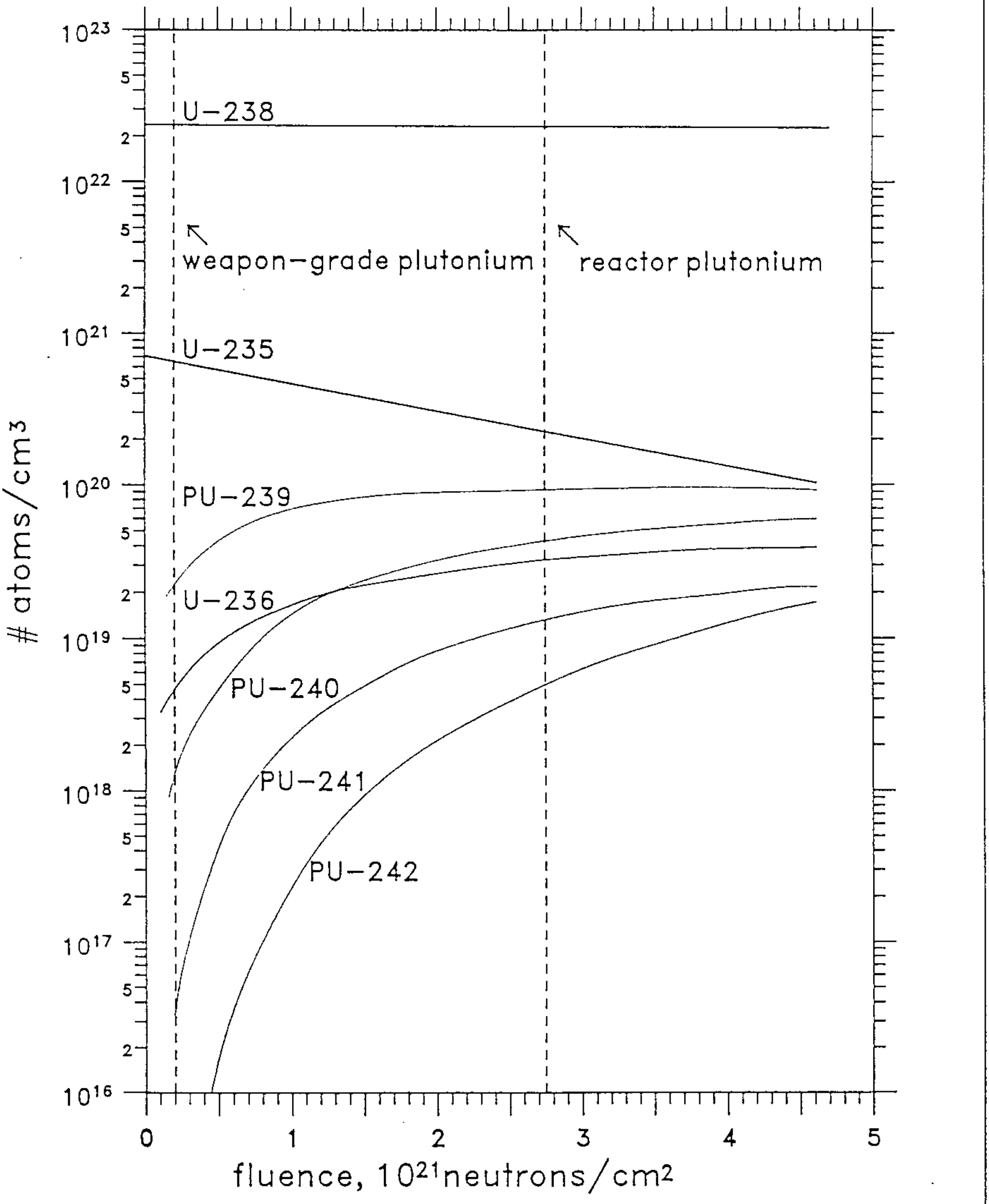
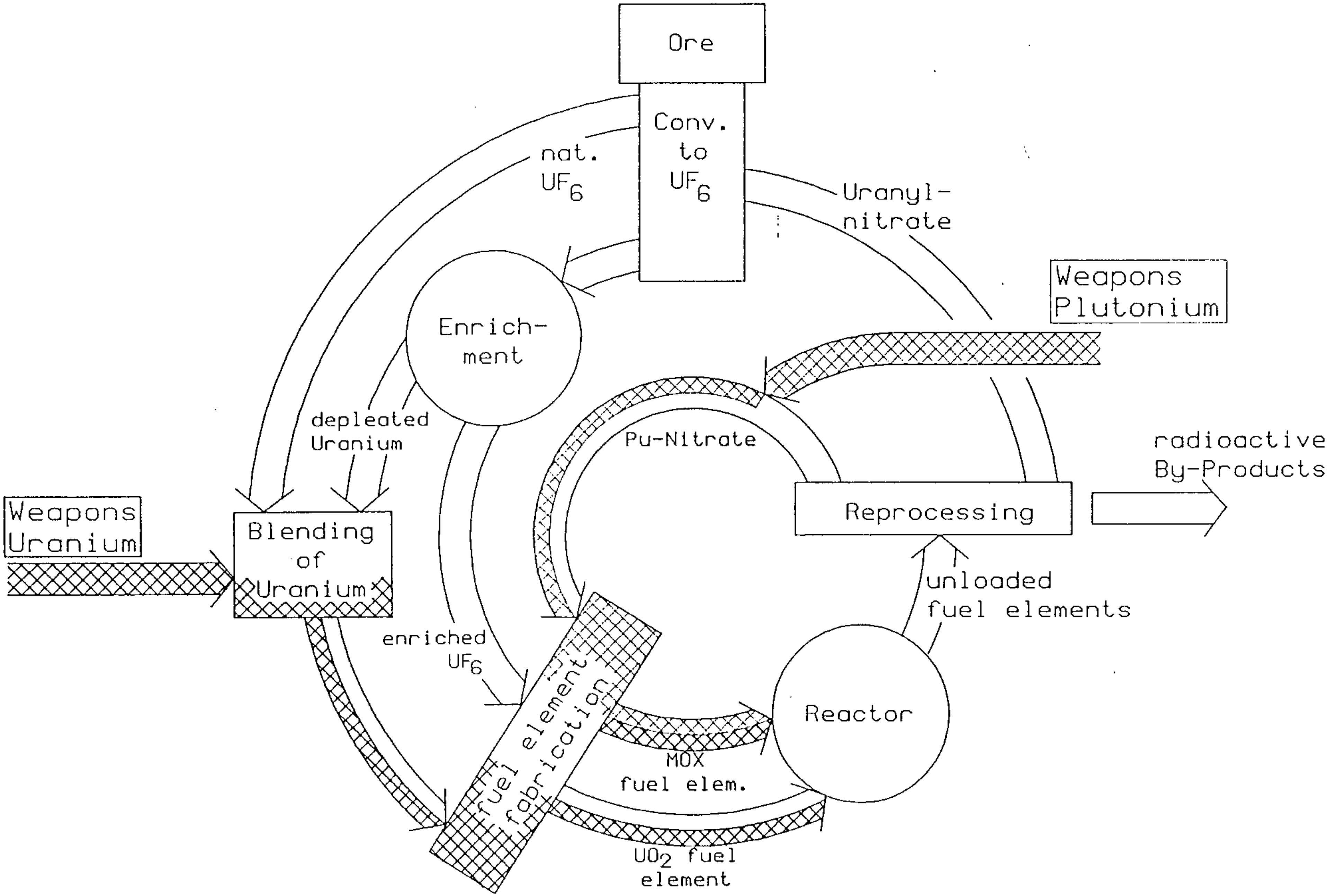


INT 20/02/92	Isotope composition in UO_2 fuel elements as a function of fluence

Fig. 1



Ore
Conv. to UF_6
nat. UF_6
Uranyl-nitrate
Weapons Plutonium
Enrich-ment
depleated Uranium
Pu-Nitrate
radioactive By-Products
Reprocessing
Weapons Uranium
Blending of Uranium
unloaded fuel elements
enriched UF_6
fuel element fabrication
Reactor
MOX fuel elem.
UO_2 fuel element

Fig. 2

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Technologies of conversion of Nuclear Materials

"Burning Weapon-Grade PU in Ad Hoc Designed Reactors ?"

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BURNING WEAPON-GRADE Pu IN AD HOC DESIGNED REACTORS ?

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1. INTRODUCTION

Plutonium has always been regarded as a profitable material, suitable substitute of natural fissile material, supposed to be available in abundant although limited quantities. Therefore, lots of efforts have continuously been carried out in order to improve the conversion ratio in nuclear reactors.

However, in any case, the utilization of plutonium does not seem, so far, to be profitable enough.

In fact, plutonium recycle in thermal reactors, although technically solved, is not attractive from an economic standpoint. Moreover, some well known related problems would adversely affect the management of the nuclear fuel cycle. In particular, any operation concerning plutonium must critically be scrutinized to avoid diversion of fissile materials. Plutonium transportation, under this aspect, is regarded as a critical issue. Last but not least, plutonium recycle can only be repeated a quite limited number of times, because of the increasing production of highly neutron absorbing isotopes.

Fast reactors were devised just to obtain a positive breeding gain: plutonium is continuously recycled and its quantity increases with a reasonable doubling time, so to render eventually possible the construction of new reactors. However, the utilization of fast reactors seems now to be postponed in the far future. Economic penalties, more than political objections and technical difficulties, are the major draw-backs for a rapid introduction of this option. When a technological application is pushed forward for a conspicuous number of years, it will be probably substituted by alternative solutions, which could be developed in the meantime. To be concrete, a thermal converter, obtainable as an evolution of present reactor concepts, might become a serious competitor to fast reactors, especially if reactor power densities are lowered, as it does occur in the new concepts.

Plutonium disposal, either permanent or temporary, is a tricky problem. If plutonium is stored as a purified material coming from fuel reprocessing, its value decreases with time, due to the gamma emitter americium build up, which makes fuel fabrication more complicated. On the other hand, the disposal of nuclear fuel wastes with their plutonium content becomes more problematic, because of the high toxicity and the very long radioactive life, that reaches a geological duration.

Apart from these considerations, which are technically debatable, there is the problem of the uranium market, at present highly depressed by an excessive offer. This situation is not expected to change within an appreciable number of years. In fact, the projections of present demand and offer can be hardly modified by any future unpredictable event, as in the case of the fossil fuel market.

Plenty of uranium and plenty of plutonium is a real contradiction, which seems difficult to be handled in the present context, and the additional availability of uranium and plutonium coming from war-heads makes the things worse.

2. A PLUTONIUM BURNER REACTOR?

If the above considerations are correct, it turns out that the plutonium problem is really a serious one. Let us face it in a rather provocative manner. Why should we not regard plutonium as a refuse instead of a profitable material? Given this reversal of a common belief, the current technical solutions, which are oriented to plutonium exploitation, are to be substantially revised.

A refuse is a material to get rid of, and, whenever possible, to be also exploited for a profit, but any further production of it during its elimination is to be impaired. In other words, the production chain must be interrupted at the early steps.

Some signals on this change of attitude have already crossed the nuclear community. Incidentally, someone suggests the adoption of fast reactors having a negative breeding gain, in order to simplify the reactor design and make its operation more economical. This proposal may be interpreted in the following way: an ever growing plutonium production is no longer the goal, and hence the already stored quantities, and those continuously produced by thermal reactors in operation, have to be exploited as soon as possible, thus obtaining prompt advantages rather than higher but uncertain returns in the future.

If this is the case, why should we not think to develop special reactors almost exclusively fed with plutonium and devoted to its burning? Obviously, a completely different fuel is to be conceived, in which uranium-238 is scarcely present or is absent at all, so as to avoid any further plutonium production. It is also to be noted that nuclear reactors fueled with fissile materials alone should be different from normal commercial reactors. On the other hand, the development of such peculiar machines might perhaps be based on already existing schemes, studied and tested in fields other than civilian.

In synthesis, a plutonium burner reactor implies fabrication of a special fuel element, in which the almost pure fissile component is spatially diluted within a proper pin. The diluent should not be a fertile material, such as in uranium based pellets or bars, but rather a matrix highly resistant to radiation, scarcely neutron absorbent, and with good thermo-physical properties. For instance, aluminum or zirconium based matrix materials are possible solutions.

Whatever be the origin of plutonium, either reprocessed fuels, with the related problems due to the presence of different plutonium isotopes, or war-heads, with the advantage of almost pure plutonium-239, peculiar technologies have to be adopted in the fabrication of fuel pins or rods. Thus, just to mention some of them, co-precipitation of fissile with matrix elements from solutions in a process which brings to mixed oxides, or absorption, selective or not, of fissile ionic compounds on suitable porous carriers, followed by heat treatments or similar techniques. Alternative and more sophisticated ways may be cermets or eutectic alloys or, for liquid state fuels, molten salt or liquid metal mixtures.

The fissile element is plutonium, or possibly a mixture of plutonium and highly enriched uranium, if technically advisable to facilitate the reactor design. In particular, this uranium can be that obtained by war-heads. It is important to exploit any existing experience to reduce or avoid long and costly development programs.

Obviously, this is a solution to be managed directly by the Nuclear Powers, in order to fully guarantee the non proliferation of military grade material.

In conclusion, let us summarize this scenario. Thermal reactors should be flanked, in the future, by plutonium burning reactors. Irradiated fuel from thermal reactors is reprocessed and the recovered plutonium should not be recycled in the same reactors, to avoid any additional plutonium production. Then this material is used to feed plutonium burner reactors, where the lack of fertile material avoids the production of further plutonium. In addition, and this is the today subject, such reactors can be used to burn military grade plutonium, so to solve the problem of its safe and fruitful disposal.

By this way plutonium build up is strongly reduced, because shortly after its production it can be profitably destroyed.

Energy exploitation of this fissile material in the plutonium burner reactor should almost equal that attainable through a single recycle in a thermal reactor. As a consequence, we miss the plutonium left after this recycle, a residue which would be hardly recycled again and therefore should be kept in stand-by for fast reactor commercialization. This condition might never be realized, if, in the meantime, other alternatives, including thermonuclear fusion, would become available. In any case, it would be easy to revert again to plutonium treasuring, if new perspectives would change the outlook.

We are now facing an intriguing alternative: either save plutonium for an unpredictable profit in the future or destroy it immediately after its production, to eliminate any proliferation and safety problems, but with a possible future economic penalty: an important strategic choice which should be worth a better insight by our community.

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Technologies of conversion of Nuclear Materials

"Plutonium Burning in Fast Reactors and as MOX Fuel"

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There are at present two ways, which have been demonstrated at an industrial scale, to burn plutonium in nuclear power plants, namely to use it as a fuel either in LWRs or in fast neutron reactors.

I will briefly describe the experience we have acquired in France on both of them.

1) First in LWRs.

At present 16 PWRs of 900 MWe each are licenced in France to operate with one third of their core loaded with so called mox fuel, containing on an average 6 % of plutonium and 94 % of depleted uranium, instead of the usual fuel made of uranium enriched up to 3.5 % of ^{235}U.

Seven PWRs of 900 MWe are already running that way in France. In three of them mox fuel assemblies have been irradiated up to the planned burn up of 33 GWd/t and removed from the reactors after three one year cycles of irradiation. Without going here into technical details, I can say that the results of these irradiations are very satisfactory. They show that, within the limits I mentioned, mox fuel has been qualified for industrial use in LWRs. When the 16 licenced 900 MWe PWRs will operate with mox fuel at an equilibrium regime, the total amount of plutonium present in their cores at any given time will be about 24 tons, and the total hold-up of plutonium in their overall associated fuel cycle will be roughly two to three times larger, i.e. of the order of 60 tons.

Under normal operation, those 16 PWRs will need each year an input of 130 tons of mox fuel containing a total of 8 tons of fresh plutonium. Each year the same

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amount of irradiated mox fuel will be taken out of them. Those 130 tons of spent mox fuel will contain roughly 6 tons of plutonium of lesser value, because the share of non-fissile isotopes in the plutonium goes up with the irradiation.

The facilities required to manufacture the quantities of mox fuel just mentioned are already existing or under construction. The present ones, at Dessel in Belgium and at Cadarache in France, can fabricate each year a total of 50 tons of mox fuel. Within a few years, a new plant called Melox, the nominal capacity of which will reach 120 tons of mox fuel per year, will go into service at Marcoule. By the turn of the century, the total amount of mox fuel produced in those three plants will be about 170 tons per year, which represents an annual flux of roughly 10 tons of plutonium, more than enough to meet the needs of the reactors.

At present no irradiated mox fuel has yet been reprocessed in France, except small quantities in pilot facilities. When the UP2-800 plant will be in full operation at La Hague, within a few years, it is planned to start reprocessing the spent mox fuel in a very progressive way, by mixing it with larger quantities of irradiated fuel made of slightly enriched uranium.

Studies and tests are under way in France with a view to increase the burn-up of mox fuel in the future up to 45 GWd/t or even more.

In present French PWRs, which have been designed for using a fuel made of slightly enriched uranium, it does not seem feasible, for the sake of safety, to increase significantly beyond one third the share of mox fuel in their cores. But studies are now being carried on for designing advanced PWRs, to be built after the year 2000, the core of which would use only mox fuel assemblies. As a mere indication, a PWR of 1000 MWe optimized to burn solely mox fuel would require 1.5 ton of fresh plutonium each year and would produce during the same period 1.2 ton of degraded plutonium, which means that on the whole it will burn a net amount of 300 kilos of plutonium per year.

It must be stressed that burning of plutonium as mox fuel in LWRs, though entirely demonstrated, is faced with inherent limitations. First, as this is the case in any reactor using slow neutrons, at the same time plutonium is consumed by fission, roughly two thirds of the quantity which has been burnt is reproduced from the ^{238}U present in the core. That means that the actual rate at which plutonium disappears is low, at most of the order of 300 kg per year for a 1000 MWe LWR. More important, as I already mentioned, the quality of plutonium as a fuel in a LWR decreases continuously as the irradiation goes on. Indeed, it cannot be recycled more than a few times. The best way to re-use it is to mix it with plutonium produced in standard reactors burning fresh fuel made of slightly enriched uranium.

Thus, burning of mox fuel in LWRs cannot be considered as a permanent and final solution. Yet it represents a very attractive possibility for many decades to come.

2) Second, in fast neutron reactors.

Plutonium is the fuel best suited for use in a fast reactor, far better in that respect than highly enriched uranium, which may only be considered as a second rate and temporary alternative. Besides, fast neutron reactors are much less sensitive than slow neutron ones to the quality of plutonium they use, that means that they are able to burn plutonium of any isotopic composition occuring in practice.

If the mixture of plutonium and uranium to form the fuel of a fast reactor is appropriately chosen (roughly 20 % of plutonium and 80 % of depleted uranium), the quantity of new plutonium produced in the core and the blanket of the reactor can be made significantly larger, by say 20 %, than the quantity of plutonium consumed by fission during the same time. Used in such a way, fast neutron reactors are called

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breeders. They have the unique ability to make available the whole of the fission energy potentially present in the uranium and thorium existing in the earth crust. This remarkable feature is the reason of the great interest taken in this type of reactor since nuclear energy started to be used.

A number of prototypes have been built in several countries to explore the feasibility of breeding at an industrial scale. The last one to operate is the 1200 MWe Superphenix power station, which is a European undertaking of which Italy holds a one third share.

At present, when there is plenty of plutonium produced worldwide and the market price of natural uranium is very low, this possibility of breeding has lost -temporarily- its economic attractiveness.

But contrary to the case of slow neutron reactors, it is possible to design fast neutron reactors in such a way that the amount of plutonium they reproduce be regulated at will. Carrying matters to extremes, one can imagine a fast neutron reactor the core of which would contain only plutonium and no uranium at all. Such a reactor would be operated as a true plutonium incinerator. As a mere indication, a 1000 MWe fast reactor specifically designed for that purpose would burn about 700 kilos of plutonium per year.

3) To conclude my talk, I would add a few words concerning the possibility to burn in nuclear power plants plutonium coming from nuclear warheads.

Military plutonium is made of almost pure ^{239}Pu (say 93 % of it). On the other hand, the plutonium used in nuclear reactors contains only roughly 70 % of fissile isotopes (^{239}Pu, ^{241}Pu), the remaining 30 % being made of non-fissile even isotopes (^{238}Pu, ^{240}Pu and ^{242}Pu). That shows that nuclear power stations are much less demanding than nuclear weapons as regards the quality of plutonium.

Thus an interesting way to store plutonium coming from dismantled nuclear warheads would be to mix it with plutonium produced by nuclear reactors. Such a mixing would improve the value of plutonium intended for peaceful purposes and would at the same time make it increasingly unfit for the manufacture of new weapons. In addition, it must be recalled that ^{241}Pu is radioactive with a half-life of 14 years and decays progressively into ^{241}Am, which is an emitter of energetic gamma rays.

After only a few years, plutonium containing a few percents of ^{241}Pu becomes increasingly difficult to handle, requiring the use of very elaborate, shielded and remote controled equipment.

Thus the problems related to the safe storage of military plutonium and to its re-use for civil purposes are not of a technical nature. Indeed what matters is the relative amount of military and civil plutonium available.

It is said that the total amount of plutonium in nuclear warheads, mainly in the US and in the former USSR, is about 200 tons. On the other hand, the cumulative amount of plutonium produced in nuclear reactors worldwide can be estimated to reach now 700 tons and to increase by about 60 tons every year.

At first sight there should be little problem to introduce progressively even up to 200 tons of military plutonium into a much greater quantity of existing civil plutonium. But the point is that most of this civil plutonium is not available at present and is not even planned to be used in the foreseeable future. Indeed, in many countries and in particular in the U.S., which is the largest producer, this plutonium remains trapped in spent fuel assemblies which are stored in pools without any prospect of being reprocessed up to now. The cumulative amount of plutonium which has been separated so far for civil purposes worldwide is of the order of 100 tons only.

The reprocessing and refabrication capacities for civil plutonium in the whole world are roughly 10 tons/year at present. They are expected to reach about 30 tons/year by the year 2000, which would meet or even exceed the needs of the LWRs licenced to use mox fuel and of the few fast reactors likely to be operating by the turn of the century.

As a conclusion, I do not see how the military plutonium could be efficiently turned to peaceful purposes as long as the use of mox fuel in LWRs does not expand to a large extent in the world.

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Technologies of conversion of Nuclear Materials

"Safeguards in a Evoluting Nuclear Environment"

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Safeguards in an evolving nuclear environment

Abstract

The dismantling of tactical and strategic warheads, foreseen in the coming years, will liberate very large quantities of nuclear materials of high strategic value, which will probably leave the military cycle, will have to be stored and could be used eventually in the civil nuclear fuel cycle later on.

It is important that as soon as these nuclear materials become available, they are submitted to an adequate international control system. Discussions are being conducted presently between directly concerned countries and at international level in order to define the inspection regime to be applied to these materials.

One may expect that the basic principles of nuclear safeguards, applied today to the civil nuclear fuel cycle, would also be applicable to the nuclear materials coming from the dismantling of nuclear warheads.
These principles are based on the declaration by the operator that has nuclear materials under his custody, on independent verification by measurements, and on the assurance of the continuity of knowledge relative to the flow of nuclear materials and its storage.

The JRC has developed, for many years, safeguards techniques and provided extensive technical support to the EURATOM and IAEA inspectorates, including training of inspectors for the implementation of their verification activities in the civil nuclear fuel cycle. These techniques include :

- the design and implementation of computerised accounting and auditing systems capable of meeting safeguards needs. This covers the design of database structures, user applications, data transmission problems and statistical analysis of accountancy data;

- the development, construction, calibration and installation of instruments for the non destructive determination (NDA) of the isotopic composition and total amount of uranium and plutonium in a large variety of materials in different parts of the fuel cycle;

- the development, construction and installation of multisensor optical surveillance systems in large storage areas, including the automatic review of video tapes;

- the development and application of ultrasonic sealing and identification techniques for a variety of containers and items;

- the study of instruments and related software for the remote handling of inspection equipment.

Much emphasis has been put in recent years on the performance assesment and the training of inspectors for the techniques mentioned above. Specialised facilities have been built for this purpose, such as PERLA for non-destructive assay, LaSCo for surveillance and sealing techniques, TAME for liquid mass determinations in large tanks, and PETRA for tests under hot conditions.

The type of techniques, which could be applied for the control of nuclear materials leaving the military cycle, is expected to be similar to those applied in the civil fuel cycle; these techniques need however to be adapted and studies have to be performed, which adress the specific applications. One may envisage presently the following subjects :

- development of information management systems for large storage areas. This will be concerned with the way in which the operator's accounting system is to be integrated with auditing information requirements in systems involving sealing, unattended monitoring and verification measurements.

- isotopic measurements by NDA of weapons grade material in the form of metal or oxide, in particular for Pu and, if required, for transplutonium elements;

- development of NDA instruments for the assay of total U and Pu in specific transport and storage containers and study of the appropriate interpretation models of the measurement results;

- development of integrated monitoring systems, involving video surveillance, radiation monitoring and other sensors operated in an unattended way and combining local intelligence for the automatic analysis of video and radiation data with remote access to information;

- development of uniquely identifiable sealing systems applicable to transport and storage containers or to storage cells with possible remote interrogation of seal identity and integrity;

- application of teleoperation devices for performing verification activities in areas of difficult access to inspectors;

- personnel training in all the technologies of measurement, sealing, surveillance and unattended monitoring. Existing JRC test and training facilities will require some adaptation and upgrading.

Before starting any specific studies, it is absolutely necessary to have a more clear idea on two issues. The first is to know what type of centralised nuclear material storage areas will be established in the future (general layout and safeguards related features). The second issue is related to the inspection regime which would be applied on the storage areas, including the input and output. Due to the complexity of the matter, one may not expect to receive clear indications on the above issues within a short time period and one could develop a few technical scenarios as a working hypothesis. The results of the studies could then be used as a safeguards input to the design or to the adaptation of these special facilities.

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(17)

THE BURNING OF THE URANIUM ORIGINATED BY DISARMAMENT IN NUCLEAR POWER STATIONS

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- URANIUM MADE AVAILABLE BY NUCLEAR WEAPONS DISMANTLEMENT ASSUMED TO BE BURNED IN LWR's

- LWR's ARE THE MOST COMMONLY USED IN OPERATING CIVIL NUCLEAR POWER PLANTS; THIS WILL ALSO BE TRUE IN THE REFERENCE TIME SPAN FOR THE PROJECT (15 YEARS)

- OPERATING NUCLEAR POWER PLANTS IN THE WORLD (SOURCE: OECD/NEA "NUCLEAR ENERGY DATA", 1989):

A .	NUMBER OF OPERATING PLANTS AS OF 01.01.1990	415
.	CORRESPONDING ELECTRICAL POWER	APPROX. 315 GWe
.	ELECTRICAL POWER FROM PLANTS WITH ENRICHED FUEL	APPROX. 294 GWe
.	ELECTRICAL POWER FROM LWR'S	APPROX. 270 GWe
.	FRACTION OF POWER FROM LWR'S	85%
B .	EXPECTED NUMBER OF OPERATING PLANTS AS OF 01-01-2005	493
.	CORRESPONDING ELECTRICAL POWER	APPROX. 400 GWe
.	ELECTRICAL POWER FROM PLANTS WITH ENRICHED FUEL	APPROX. 374 GWe
.	ELECTRICAL POWER FROM LWR'S	APPROX. 350 GWe
.	FRACTION OF POWER FROM LWR'S	87%

- TYPICAL CORE CHARACTERISTICS AND REFUELING STRATEGY OF LARGE SIZE LWR's

	PWR 900 MWe	BWR 1000 MWe
THERMAL POWER, MW	2775	2894
URANIUM MASS IN THE CORE, t	72.5	113.8
POWER DENSITY, W/cm^3	104.5	52.4
SPECIFIC POWER, W/gU	38.3	25.4
AVERAGE LINEAR POWER DENSITY, W/cm	177	188.5
REFUELING STRATEGY	ANNUAL	ANNUAL
ANNUAL LOAD OF FRESH FUEL (CORE FRACTION)	1/3	1/4
AVERAGE REFUELING ENRICHMENT (w%)	3,25	2,78
DISCHARGE BURNUP (GWd/t_U)	33	28
NET PLANT EFFICIENCY	0.33	0.339

WARHEADS NUMBER IN MILITARY ARSENALS, AMOUNTS AND ENRICHMENT OF FISSILE MATERIALS
(SOURCE: T.B. TAYLOR: "VERIFIED ELIMINATION OF NUCLEAR WARHEADS", SCIENCE AND GLOBAL SECURITY, 1989, VOL.1)

- NUCLEAR WARHEADS TOTAL NUMBER IN MILITARY ARSENALS		56000	
- TOTAL AMOUNTS OF FISSILE MATERIALS AND TRITIUM	U	APPROX. 1000 t	
	Pu	APPROX. 200 t	
	Tritium	APPROX. 200 kg	
- FISSILE MATERIALS ENRICHMENT	U	93%	U235
	Pu	> 90%	Pu239
	Tritium		-

- BURNING OF URANIUM ONLY ANALYZED
- DILUTION WITH NATURAL URANIUM ASSUMED

- CURRENTLY PREVAILING CYCLE LENGTH IS 12 MONTHS;

- EXTENSION OF OPERATING CYCLE LENGTH HAS BEEN INVESTIGATED BY UTILITIES WITH THE AIM TO REDUCE POWER GENERATION COSTS

- 18 OR 24 MONTHS CYCLE LENGTH FEASIBILITY ASSESSED

- POTENTIAL BENEFITS FROM CYCLE EXTENSION:

  . REDUCTION IN NUMBER OF PLANT OUTAGES (HIGHER AVAILABILITY FACTOR)

  . LOWER POTENTIAL FOR OUTAGE DURING HIGH POWER DEMAND PERIODS (REPLACEMENT POWER WOULD BE EXPENSIVE)

  . REDUCTION IN WORKERS RADIATION EXPOSURE

- HIGHER DISCHARGED FUEL BURNUP ASSOCIATED WITH EXTENDED FUEL CYCLES

- HIGHER BURNUP MUST COMPLY WITH THE TECHNOLOGICAL FUEL LIMITS

- CURRENT FUEL HAS DEMONSTRATED EXCELLENT RELIABILITY UP TO 50.000 MWD/TON (ASSEMBLY AVERAGE)

- A CURRENT FUEL TECHNOLOGY TREND IS TOWARDS DEVELOPMENT OF FUEL CAPABLE OF BURNUPS IN THE RANGE 60.000 - 65.000 MWD/TON (ASSEMBLY AVERAGE)

- HIGHER ENRICHMENT AND PROPER REFUELING STRATEGY REQUIRED TO ATTAIN THE ABOVE BURNUPS

- CURRENT TRENDS FOR A 24 MONTHS CYCLE

  . PWR — FUEL ENRICHMENT: 4.5% U-235
REFUELING STRATEGY: HALF CORE

  . BWR — FUEL ENRICHMENT: 4.0% U-235
REFUELING STRATEGY: ONE THIRD OF CORE

- AVAILABILITY OF HIGHLY ENRICHED URANIUM FROM NUCLEAR WARHEADS DISMANTLEMENT FITS WELL WITH ABOVE TRENDS; USE OF HIGHER ENRICHMENT FUEL IN CIVIL PLANTS MAINTAINS HIGHER ECONOMIC VALUE TO URANIUM FROM WARHEADS DISMANTLEMENT.

- IN THE ABSENCE OF DETAILED INFORMATION ON THE EXTENDED FUEL CYCLES THE POTENTIAL ELECTRIC ENERGY PRODUCTION HAS BEEN ESTIMATED WITH ANNUAL CYCLES.

POTENTIAL ELECTRIC ENERGY PRODUCTION FROM NUCLEAR WARHEADS URANIUM

BLENDING URANIUM	NATURAL
EQUIVALENT NUMBER OF 1000 MWe LWR PLANTS	270 (PWR); 83 (BWR)
ELECTRIC ENERGY BY A FUEL LOAD DURING ITS RESIDENCE IN CORE (KWH)	$6.4\ 10^{9}$
MASS OF WARHEADS URANIUM IN THE ANNUAL LOAD OF FRESH FUEL (KG/PLANT)	665 (PWR); 638 (BWR)
NUMBER OF RELOADS OBTAINABLE FROM WARHEADS URANIUM BLENDED WITH NATURAL URANIUM	1160 (PWR) + 358 (BWR)
FEED TIME OF OPERATING REACTORS BY MEANS OF WARHEADS URANIUM WITH LOAD FACTOR 0.65 (YEARS)	GREATER THAN 6
ELECTRIC ENERGY OBTAINABLE FROM WARHEADS URANIUM BLENDED WITH NATURAL URANIUM (KWH)	$9.7\ 10^{12}$

- THE ESTIMATED FEED TIME ASSUMES ALL THE LWR's ARE FED ONLY WITH FUEL FROM DISARMAMENT

- THE OBTAINABLE ELECTRIC ENERGY IS OF THE ORDER OF THE CURRENT TOTAL WORLD CONSUMPTION IN 1 YEAR

- THE ECONOMIC VALUE OF ALL THE URANIUM FROM NUCLEAR WARHEADS DISMANTLEMENT BASED ON A 12 MONTHS FUEL CYCLE IS OF THE ORDER OF 50 BILLION DOLLARS

- ADOPTION OF HIGHER ENRICHMENT URANIUM REQUIRED BY EXTENDED FUEL CYCLE LENGHTS AND HIGHER DISCHARGE BURNUP TENDS TO INCREASE THE ABOVE FIGURE