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CIVEX FUEL CYCLE: THE SOLUTION TO NUCLEAR PROLIFERATION ?

INTRODUCTION

Increasing world awareness of the near-term scarcity of energy resources has led a growing number of nations to examine the nuclear option. Interest in this energy path has been heightened by the promise of virtually inexhaustable supplies of power held forth by the development of the French "Phoenix" design breeder reactor. In the United States, however, the concepts of nuclear energy and the breeder reactor have faced escalating opposition from private groups alleging to represent environmental concerns and from some members of the Carter Administration.

One of the main reasons for this opposition has been the very real concern which exists regarding the spread of nuclear weapons. Given the fact that, in their purest forms, many fissionable materials are adaptable for nuclear weapons, such concern is understandable. Also, it is true that, in its purest form, Plutonium-239--currently a leading candidate as the fuel for the breeder reactor--is an efficient material from which to fashion a nuclear device. It is not surprising then, that some individuals make the mistaken link between the world-wide availability of Plutonium-239 fuel for reactors, and the global spread of nuclear weapons.

NUCLEAR PROLIFERATION AND PLUTONIUM

Many individuals concerned with nuclear proliferation fail to recognize that Plutonium-239 is not the only fissionable material from which an explosive device may be constructed, nor is it necessarily the most desirable. More properly, due to the current debate, Plutonium-239 might pose fewer problems for a terrorist group or nation intent on fabricating a weapon from diverted materials. Unlike Plutonium-239, which requires the use of a fairly sophisticated implosion technique to be exploded as a bomb, Uranium-233 is more amenable to the simpler "gun-barrel" design. It may be the fact that Uranium-233 is not currently anticipated to be widely available in a form pure enough for bomb fabrication which has led to the attention to the possible diversion of supplies of Plutonium-239. Regardless of the type of material, however, the widespread ready availability in substantial amounts of any fissionable material in a form pure enough for weapons fabrication would present cause for concern.

Even when discounting the possibility of the diversion of Plutonium-239 by terrorists, there still remains the danger of a nation's diverting its supplies of Plutonium intended for commercial power reactor operations to a weapons program. There is little doubt, of course, that given the committment of sufficient resources and the existence of an adequate time frame, many nations could construct facilities for the specific purpose of fabricating pure Plutonium-239 from which to manufacture weapons. Such an undertaking, however, would require a level of effort far greater than a simple act of diversion of existing commercial supplies.

TERRORIST DIVERSION VS WEAPONS PROGRAMS

It is evident then, that the widespread availability of relatively pure fissionable materials could create two separate problems. The first would be the possibility, no matter how remote, that a dedicated band of terrorists could divert a portion of the supplies intended for commercial uses and with them construct a crude explosive device. Ignoring for the moment the technological problems associated with such an undertaking, it should be clear that such a threat is relatively limited in its impact in global terms. The effect essentially would be confined to the nation which was the target of the terrorists' activities.

The second and far greater problem stems from the possibility of a government diverting the output of a facility intended to produce fuel for commercial reactor operations to a military weapons program. It should be emphasized that the fissionable materials contained in a reactor's core pose no weapons threat. They are far too hot, in both a thermal and a radiological sense to allow access. Further, such materials would be of insufficient purity due to the creation of fission products by the normal course of operation of a chain reaction to be of use in fabricating weapons. Therefore, only those segments of the fuel cycle during which fissionable materials in a relatively pure state exist outside a reactor afford opportunities for diversion. It is these stages, then, which must be the focus of any attempt to limit the proliferation of nuclear weapons.

If the proliferation of nuclear weapons is to be curtailed, the problem of a government diverting commercial fuel to a military weapons program must be satisfactorily resolved. Further, it must be resolved in a fashion which does not violate the national sovereignty of the nations concerned. Otherwise, non-nuclear nations would reject it out of hand. It is undoubtedly a difficult and sensitive dilemma. However, it now appears that an answer is on the horizon. Recently, the Electric Power Research Institute announced the development of an alternative fuel cycle. Called "Civex," to differentiate it from the military "Purex" fuel cycle, the EPRI breakthrough appears to meet all of the criteria necessary to insure that fissionable material intended for commercial power reactor operations is not suddenly diverted to a military weapons program. Also, as the safeguards contained in the Civex cycle are an intrinsic part of it, it is technologically impossible to make a series of simple adjustments to the process which would circumvent its purpose. Perhaps the single most encouraging aspect of the proposed Civex fuel cycle is that it utilizes relatively well known technologies. As a result, it can be implemented within a fairly brief time. For those concerned with stemming the tide of nuclear weapons proliferation, there can be little doubt that the relatively brief lead-time will be a major advantage to this approach.

HOW CIVEX WORKS

In order to sucessfully prevent the diversion of Plutonium-239 from commercial reprocessing facilities safeguards must be designed to account for the two separate contingencies referred to earlier. The first of these is the possibility of a band of terrorists diverting a relatively small amount of pure Plutonium-239 and with it manufacturing some sort of crude explosive device. The second, and from a proliferation standpoint more serious problem, is that of a government suddenly diverting the output of its commercial reprocessing facilities to a relatively sophisticated weapons program. Each of these two contingencies presents a unique set of problems. However, it appears that they may be susceptible to a common solution.

In addressing approaches to the prevention of the above mentioned contingencies, it is necessary to first clearly define what is meant by sudden diversion. Conceptually, "sudden diversion" differs in substance from the development of a carefully planned weapons program. There is little doubt that many nations could develop nuclear weapons given the committment of sufficient time and resources. In fact, at present six nations already possess functioning Purex reprocessing facilities. Since such facilities produce pure Plutonium-239, all of these nations possess nuclear weapons capability. In addition to the six, there are another fifteen nations which are known to have the technological capability to construct a Purex plant. If any of these were truly intent on fabricating atomic weapons, they would be able to do so.

A second consideration related to the existence of Purex plants is that they present optimum targets for terrorist diversion. The Plutonium-239 produced in these plants is ultimately refined to a form pure enough for bomb fabrication--even the crude sort of weapon which would be the tool of a terrorist group. Therefore, diversion of the output of a Purex plant by terrorists holds a certain very real risk.

The key to preventing sudden diversion, then, is to develop a form of reprocessing which does not produce bomb-grade Plutonium-239 at any stage. By following this approach, the output of the reprocessing plant holds no attraction for the potential terrorist or weapons program, as it would be worthless for construction of an explosive device. This approach is an integral part of the proposed Civex fuel cycle.

On the surface, the Civex fuel cycle closely resembles the conventional method of reprocessing spent fuel. In the first step, similarly to the Purex fuel cycle, spent fuel rods are chopped up and dissolved in a nitric acid solution. The solution is separated into two streams. This is accomplished through the use of a conventional tributyl-phosphate-nitric acid solution. One of the streams contains the excess uranium from the spent fuel. This material will be returned to the blanket of a breeder reactor for enrichment. The second stream contains a mixture of Plutonium-239, Uranium, and fission products. Fission products are what we commonly refer to as high-level wastes. The ratio of Uranium to Plutonium is maintained at roughly four to one throughout the process, with a small portion of the total volume being accounted for by fission products. The maintenance of a four to one Uranium-Plutonium ratio, and the continued presence of fission products are what differentiate the Civex process from the Purex process. They also represent the key to the inherent invulnerability of the process to sudden diversion.

FISSION PRODUCTS

Fission products are the result of the normal operation of a chain reaction. They are commonly referred to as nuclear wastes. Actually, they consist of two basic components. The first are what are termed "fission fragments." These fission fragments are pieces of larger atoms which have been split by the chain reaction. Some fission fragments are radioactive and some are not.

The second component of the fission products generated by a chain reaction are Transuranics. These are elements with atomic numbers higher than uranium. As a rule, they are not found in nature, but rather are the result of neutron capture followed by beta decay occuring during a chain reaction. Normally, the fission products would be separated from the Uranium and Plutonium in spent fuel during reprocessing and later disposed of. The removal of the fission products would be accomplished through a series of successive nitric acid washes which cause the wastes to precipitate out leaving only Uranium and Plutonium. The reason for employing these successive washes is that fission products interfere with the operation of a conventional light water reactor. Breeder reactors, however, are relatively indifferent to their presence.

The purpose for inclusion of fission products in the output of a Civex reprocessing plant is that many of them are intensely radioactive. This means that their inclusion in all stages of the process insures that the entire operation will take place in a high radiation field. This being the case, physical access to the fissionable materials becomes impossible. Estimates indicate that a minimum of four feet of concrete will be necessary to shield the reprocessing streams. The radiation levels will vary to some degree, but at the very least they will range into tens of thousands of rads, and possibly into hundreds of thousands. Any individual attempting to handle the materials directly would die within minutes or possibly seconds. Because of the mechanized nature of the plant, however, there would be no danger to the workers operating it. Previous experience with Experimental Breeder Reactor No. 2 has demonstrated the feasibility of such a facility.

EBR 2

Experimental Breeder Reactor No. 2 (EBR 2), was a research reactor located at Idaho Falls, Idaho. It operated continuously for five years without mishap. The basic technology necessary for implementation of the Civex process was amply demonstrated by EBR 2's operation. EBR 2 was a totally remote operation which employed reprocessing. Fuel was removed from the core of the reactor by remotes which were afforded access through a concrete hatchway. The spent fuel was then conveyed through a corridor to a reprocessing section within the plant, where it was refabricated into fresh fuel. The refabricated fresh fuel was then returned to the reactor and reloaded through the hatchway. As would be the case in a Civex reprocessing plant, the entire operation took place within a high radiation field. Therefore, at no stage during the process was a human being able to gain access to the operation. In fact, even light bulbs were changed with remotes.

TERRORISTS AND CIVEX

Given the intensely penetrating nature of the radiation associated with the fuel fabricated in a Civex reprocessing plant, theft by terrorists is virtually impossible. Any band of terrorists exposed to the unshielded material would shortly expire. This would hold true in all possible terrorist scenarios ranging from an outright attempt to hijack materials being shipped, to more involved attempts using assistance within a Civex plant. No matter how determined a group intent on diverting Civex fuel was, aquiring it would not be within their potential technological capabilities.

A second reason why Civex fuel would be useless to terrorists is that it is not suitable for bomb fabrication. To construct a Uranium based nuclear weapon requires uranium with a purity of at least 93 percent. Plutonium-239 must be virtually pure in order to be suitable for weapons fabrication. Since the four-to-one Uranium/Plutonium-239 ratio is maintained through all stages of the Civex cycle, there would be no point at which weapons-grade material existed. Granted, with a Purex type reprocessing facility the Civex fuel could be further refined and separated so that the end-product was bomb-grade material. However, if one had access to a Purex type plant, there would be no need to divert the Civex fuel in the first place.

DIVERSION FOR A WEAPONS PROGRAM

The level of difficulty associated with utilizing the output of a Civex-type plant for weapons fabrication is essentially the same as that associated with developing a weapons program independent of any commercial power reactor program. This is because the output of the Civex cycle must be reprocessed in much the same fashion as would spent fuel in order to purify it to the degree necessary for bomb-grade material. Further, the Civex plant is so designed that it cannot be adapted to further purify materials beyond the four-to-one ratio of Uranium to Plutonium.

There are a number of technical reasons why a Civex plant cannot be converted to one of the Purex configuration. First, the space necessary for the concrete cells is essential to the multiple cycles required for Plutonium purification will not be present. This would mean that the plant would literally have to be rebuilt in order to add such cells. Special equipment would also have to be added, provided it was available to the nation in question. There also remains the problem of decontamination of the areas to which such additions would be made. These areas would have been exposed to the high radiation field in which the entire Civex operation takes place, and would be quite difficult to decontaminate.

A second reason why the Civex process is unsuitable for adaption to military purposes is that the chemical process used includes different steps than those integral to the Purex process. This difference in chemistry insures that the output of a Civex plant is unusable in weapons fabrication. Specifically, a fluoride purification process is used. This process is well-suited to Uranium purification, but not to Plutonium purification. The technology itself has been used for decades, and is still used by Allied Chemical at their Metropolis, Illinois, plant. It has also been used at Oak Ridge National Laboratory.

Initially, fluoride purification was developed in an attempt to design a system for the purification of pure Plutonium. However, it was eventually abandoned after many years of research when it was established that it was impossible to produce pure Plutonium using it. The establishment of this fact is what makes fluoride purification so attractive as a proliferation resistant technology.

REPROCESSING DEFERRAL AND PROLIFERATION

One key point often overlooked in discussions of whether or not to go ahead with spent fuel reprocessing is that delays in reprocessing increase the worldwide inventory of Plutonium. The fact is that the spent fuel rods taken from a reactor contain substantial amounts of Plutonium-239. Initially, these fuel rods are too hot in a radiological sense to readily allow for the extraction of their Plutonium content. After the passage of around a decade, however, the level of radioactivity will have been reduced to a level which makes such extraction far more feasible. In a very real sense, the delay in embarking on reprocessing results in an increase in the world's available Plutonium inventory.

While it is true that Plutonium would be extracted through implementation of Civex or some similar reprocessing system, this material so refined would be soon incinerated in a power reactor's core. In fact, one of the original reasons for considering reprocessing was that it would help to reduce the build-up of a large Plutonium inventory. The British cited this factor as a major consideration in their recent decision to go ahead with reprocessing.

CONCLUSION

It now appears that there is a viable technology which will allow the world to utilize the vastly improved energy resources represented by the breeder reactor technology, while at the same time insuring the limitation of the spread of nuclear weapons. Further, it also appears that the technology is as resistant as is humanly possible to terrorist activity. While any nation with the will to commit the necessary amounts of resources and with a sufficient lead-time could develop a nuclear weapons program, implementation of a Civex-type reprocessing system would in no way make such a program easier.

We must recognize that few nations are as richly endowed with energy resources as the United States. There can be no doubt that as energy supplies become increasingly scarce and expensive, most industrialized nations will forge ahead with the development of nuclear energy, including breeder reactor technology. To fail to recognize this fact is to play ostrich to the world's energy trends.

If we are to have a say in the uses to which nuclear technologies are applied, then we must maintain our leadership role in the area of nuclear export. This leadership role cannot be maintained however, without the development of a spent fuel reprocessing technology. In Civex, there appears to be such a technology which will both serve the needs of the international community and limit the spread of nuclear weapons. Hopefully, its development will finally put fears of weapons proliferation to rest.

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