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AND MOX FUEL FABRICATION

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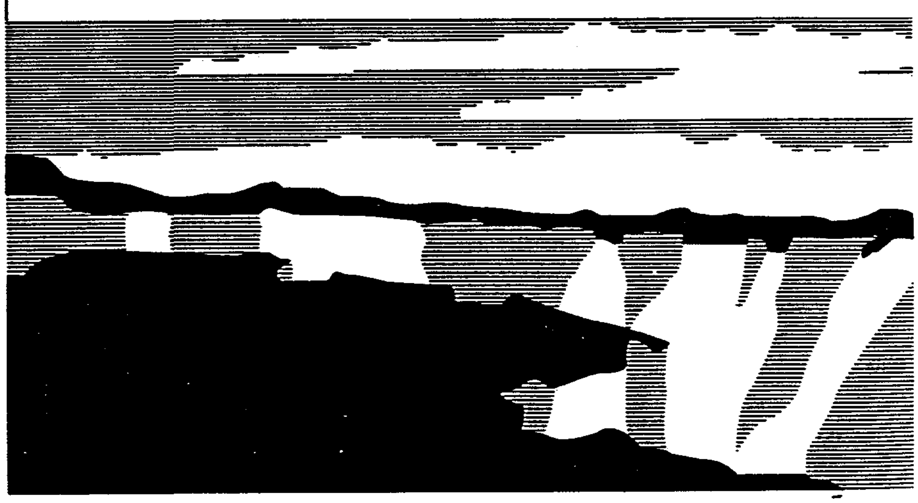

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Surplus Weapons Plutonium: Technologies for Pit Disassembly/Conversion and MOX Fuel Fabrication

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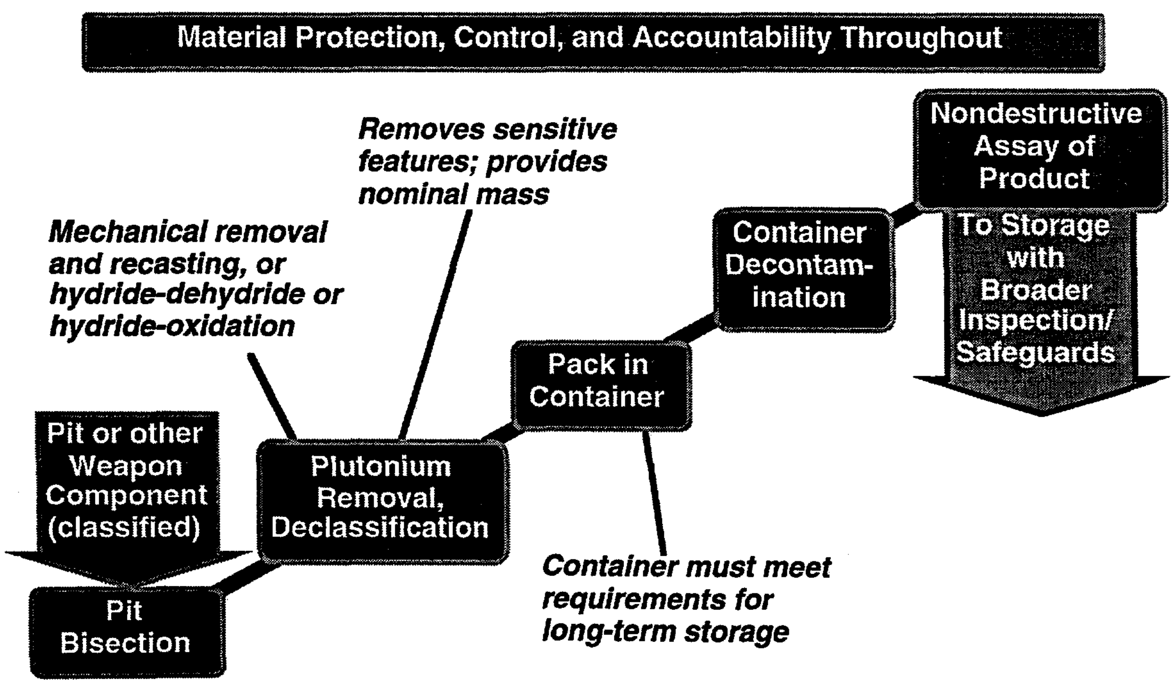
Introduction

This paper will provide a description of the technologies involved in the disposition of plutonium from surplus nuclear weapon components (pits), based on pit disassembly and conversion and on fabrication of mixed oxide (MOX) fuel for disposition through irradiation in nuclear reactors. The MOX/Reactor option is the baseline disposition plan for both the US and Russia for plutonium from pits and other clean plutonium metal and oxide. In the US, impure plutonium in various forms will be converted to oxide and immobilized in glass or ceramic, surrounded by vitrified high level waste to provide a radiation barrier. A similar fate is expected for impure material in Russia as well. The immobilization technologies will not be discussed. Following technical descriptions, a discussion of options for monitoring the plutonium during these processes will be provided.

Pit Disassembly and Conversion--Technology

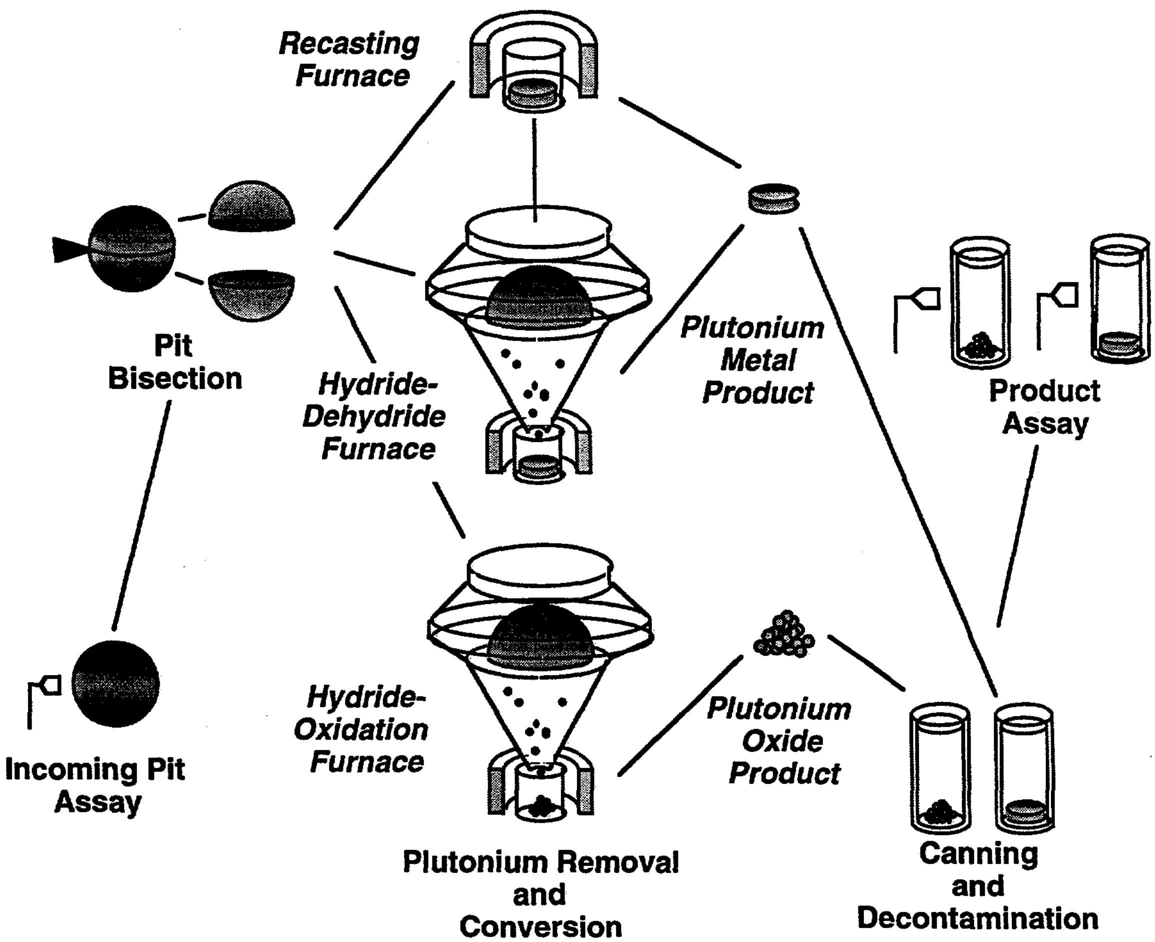
Pit disassembly and conversion refers to removal of plutonium from the nuclear weapon pit and conversion to unclassified form that is verifiable in the sense that, containing no classified information, the form can be examined by inspectors from other nations. This enabling step represents doing first things first, as placement of the material under a broader inspection - verification regime provides some level of irreversibility. This irreversibility is political, rather than physical, in the sense that any attempt by the host country to reuse the material would be announced immediately to other countries.



Generic Pit Disassembly/Conversion System

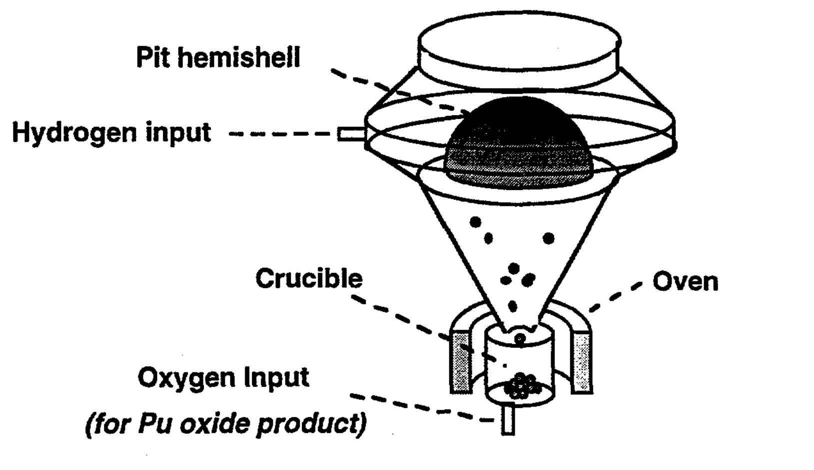
Conversion also refers to rendering the plutonium as an oxide suitable for use in the fabrication of MOX fuel. This step may be taken as part of the disassembly and conversion process, or taken just prior to fabrication of the fuel. Plutonium can be stored safely for long times as either metal or oxide. Russia intends to store surplus plutonium as metal ingots for reasons that will become clear in the discussion. For the US, the DOE Record of Decision (ROD; January, 1997) on plutonium storage and disposition allows the selection of either option.

The figure above shows the generic steps involved in disassembly and conversion. The incoming pit must be assayed to verify that the entire quantity of plutonium was shipped from the pit storage facility, and to initiate the accountability trail for this plutonium in the processing facility. The pit is then cut in half, and the plutonium removed through one of several processes. The mass of the product plutonium must not reveal the mass of plutonium in the original pit as this is sensitive design data. Therefore, plutonium mass must be added or subtracted to make up a nominal mass, typically 4 to 4.5 kg, for storage. This can be accomplished through recasting for metal, or, for oxide, mixing with other plutonium oxide powder. Metal or oxide, the plutonium product must be packaged in an appropriate container for storage, and the outside of that container must be decontaminated for safe handling. The container must be assayed to close the accountability trail for the processing facility and to initiate accountability for transportation, if required, and storage. Plutonium-bearing waste is also packaged and assayed.



ARIES Pit Disassembly and Conversion Process

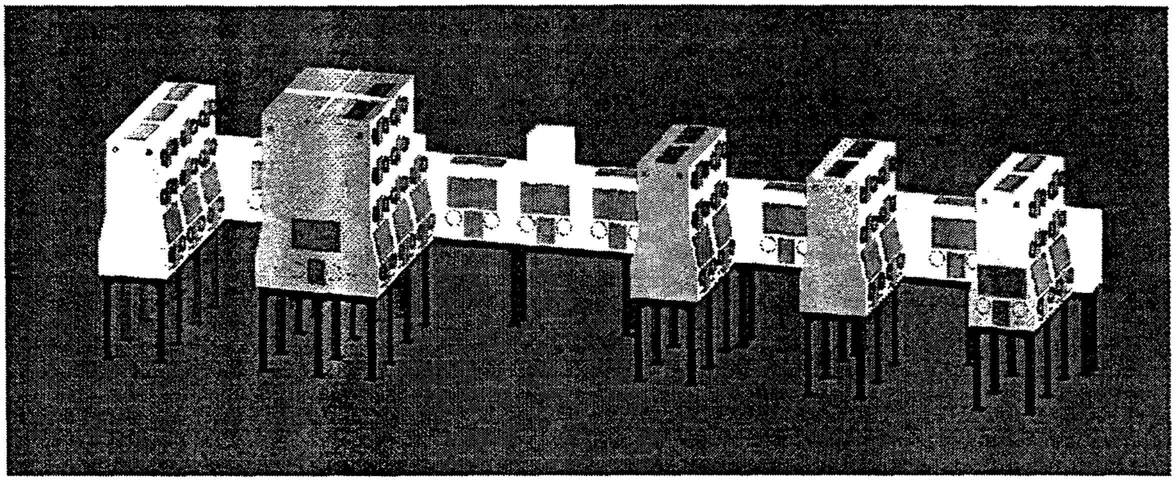
The US technology for pit disassembly and conversion is ARIES, the Advanced Recovery and Integrated Extraction System. The figure above indicates the various steps in a cartoon form. Russian technology will be similar; however, in Russian surplus weapon pits, plutonium is not bonded to other metals, so after bisection, the plutonium hemishells can simply be removed, then recast to nominal mass in an unclassified form, that is, a form containing no design information. Some US pits are not bonded, and can follow a similar pathway, as indicated by the top approach in the Plutonium Removal and Conversion section of the cartoon. In other surplus US pits, plutonium is bonded to stainless steel, beryllium, or uranium. In this case, a hydride-dehydride process will be used if metal is the desired product, indicated in the middle cartoon of the Plutonium Removal and Conversion section. For immediate conversion to an oxide product, metal can be directly oxidized in a furnace (not shown) or a hydride-oxidation process may be used. Conversion to an oxide might instead take place just prior to fabrication of MOX fuel; there are several advantages to delaying the oxide conversion until this time, including symmetry with the Russian approach.

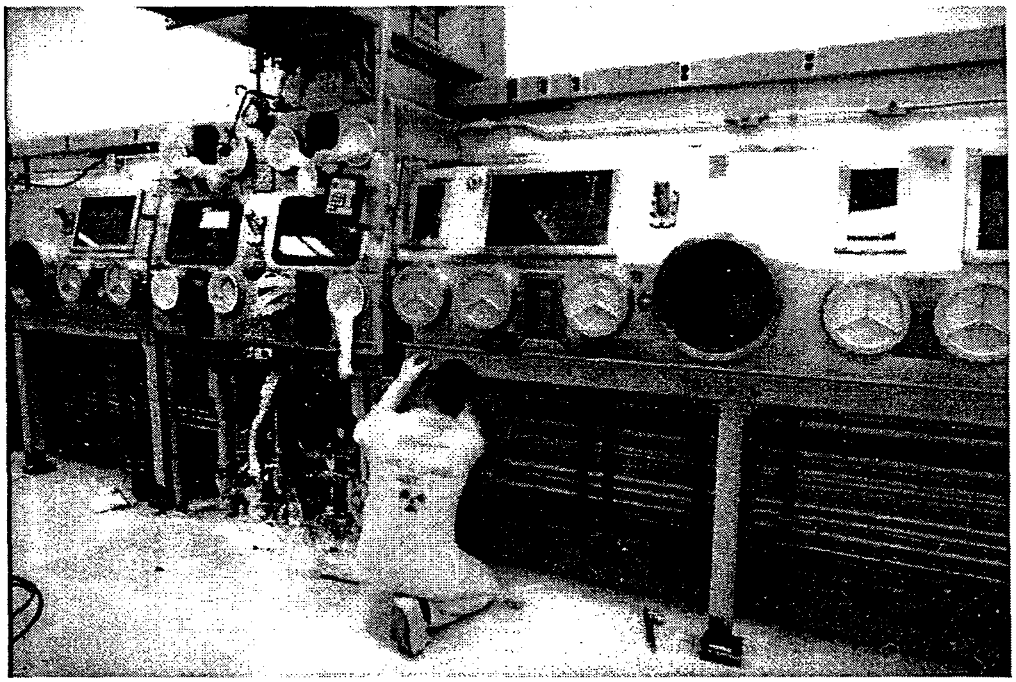


Detail of Hydride Process for Plutonium Removal

This figure illustrates these hydriding processes. They make use of the fact that plutonium forms a hydride very rapidly when exposed to hydrogen gas, and that hydride is mechanically unstable, falling away as a powder. The US process uses continuous hydrogen recycle: the hydride powder falls into a crucible that is heated by an oven, driving the hydrogen off, leaving molten plutonium metal in the crucible. The hydrogen refluxes to the top of the chamber, where it removes additional plutonium from the hemishell. Because the hydrogen gas is recycled, this approach uses very little hydrogen.

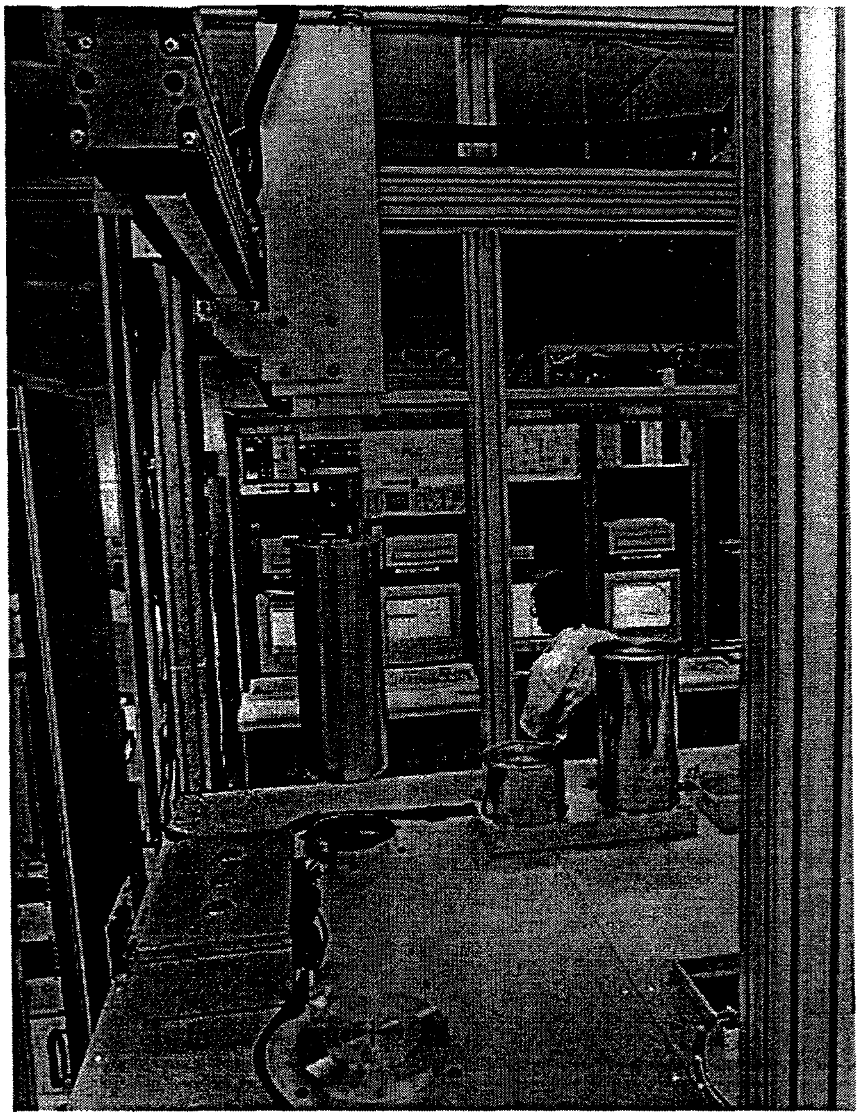
For immediate oxide conversion, the crucible is not heated, and in a two-step process, oxygen is admitted to the crucible as indicated, burning the hydride to release hydrogen gas and leave a plutonium oxide powder product. In a three-step process, nitrogen is admitted rather than hydrogen, producing plutonium nitride, which is then oxidized by admitting oxygen as before. This approach avoids having a hydrogen-oxygen atmosphere, which is not desireable in a plutonium glovebox. These two-step or three-step hydride-oxidation approaches require that all the plutonium be converted to hydride, using some 20 times as much hydrogen as the hydride-dehydride approach, and the hydrogen is mixed with oxygen or nitrogen, so it cannot be reused without a recovery system.





The processing through canning and decontamination will be performed in glovebox systems. This layout and photo illustrate the ARIES pilot demonstration system, which is being constructed in TA-55, the Los Alamos plutonium processing facility. This is a full-scale prototype demonstration, however, the production system would be configured somewhat differently, and would consist of 2 - 4 such lines. The system contains various modular gloveboxes, connected by a conveyor box. The photo shows this conveyor following installation. The large hole to the right of the worker is an airlock port for connecting a glovebox. Gloveboxes allow safely controlled plutonium operations in an inert atmosphere, typically argon or helium.

The glovebox layout does not include the nondestructive assay (NDA) system. Because decontamination takes place in the processing line, the NDA system does not need to be contained within a glovebox. The NDA system is automated with a gantry robot to reduce worker exposure and increase throughput. The system uses a combination of gamma spectroscopy, calorimetry, and neutron measurements to determine product plutonium to within ± 1/2%. Segmented gamma scanning is also used to assay waste. It

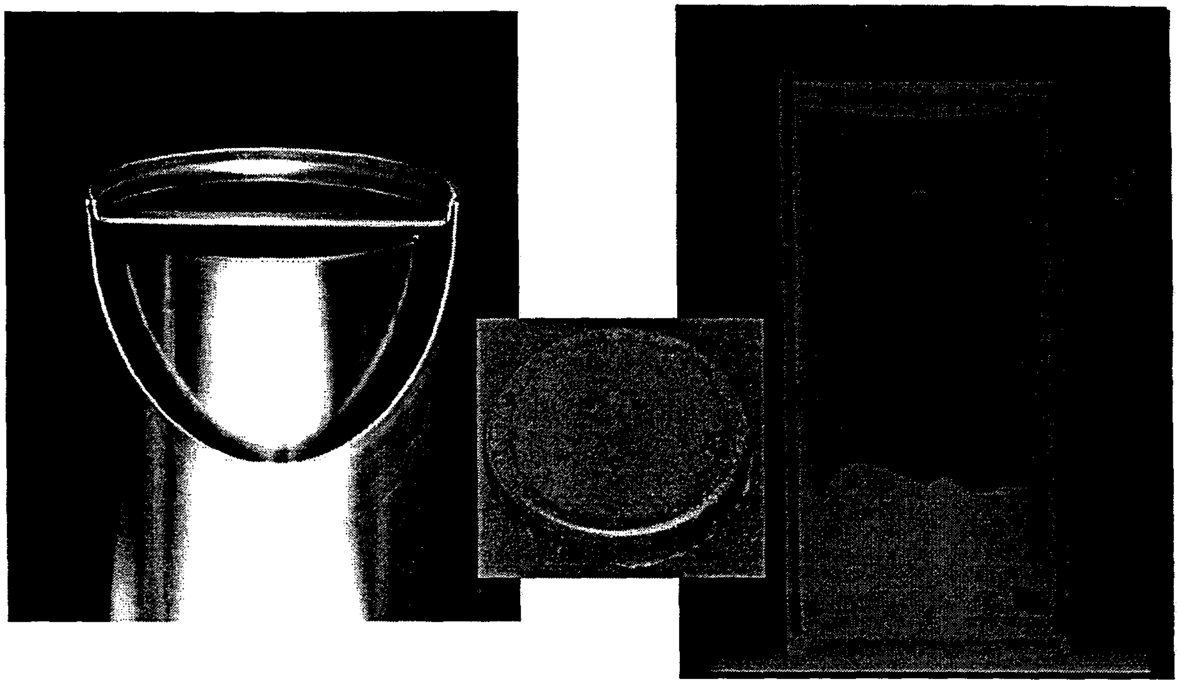


should be underscored that this assay is nondestructive--it is performed by measurements through container walls without sampling or intrusion into the product container. The figure above shows the telescoping gantry robot lifting a 20-kg shielding plug out of the neutron detector well. Data acquisition instrumentation is seen in the background.

Pit Disassembly and Conversion--Monitoring

As mentioned earlier, pit disassembly and conversion represents the transition from classified material to material that can be inspected freely. Until agreements are in place that allow bilateral sharing of sensitive information at some level, the only option available for incoming pits is item accounting, or limited measurements that reveal no classified data--including plutonium mass.

During the processing operations described above, accepted--and required--procedures for material monitoring and accounting will be used in the production facility. However, these data also will be sensitive and cannot be revealed to inspectors from other countries. Once the material is converted to unclassified form, either metal or oxide, it can be observed and perhaps even sampled. However, given the nature of plutonium processing and the connected glovebox lines, inspection or sampling anywhere in the glovebox processing line would entail closing down operations to protect classified information in the early stages of processing. Hence, such inspection or sampling would be invasive, and would reduce throughput.



To ensure safe, long term storage, the container is double-walled stainless steel, welded, and backfilled with helium. This construction is illustrated above with the cutaway view on the left. A plutonium metal ingot from the hydride-dehydride operation is in the center. The radiograph on the right illustrates the construction once again. A small sealed bellows in the top of the container can indicated pressure change through radiography. With this construction, sampling after packaging would be intrusive, difficult, and costly.

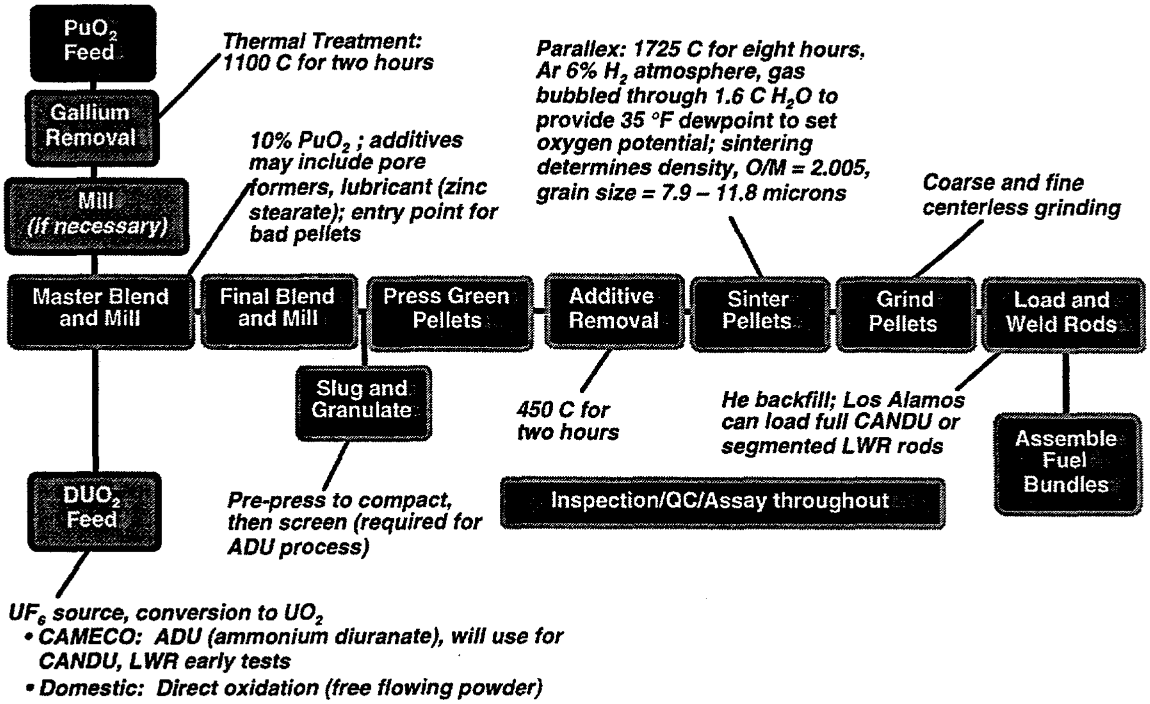
The best option is to introduce inspection without sampling, that is, NDA, at the same point at which we perform our own NDA operations. Because our NDA system is separate from the processing gloveboxes, it is a simple matter to construct a wall between the gloveboxes and the NDA system. Inspectors--IAEA or other--could use their own instrumentation or rely on ours. In either case, resolution of questions and discrepancies must begin with comparison of standards.

It should be noted that, although the mass of a particular pit can be protected through these procedures, the average mass of the surplus pits will become available at the end of the campaign--simply the total plutonium mass coming into inspection and verification divided by the number of items going in. We can imagine two methods for masking this information, although neither seems worthwhile. The first would be to include items coming into the facility that do not contain pits but even limited measurements to verify presence of fissile material would eliminate this option. Second, plutonium from scrap and residues throughout the complex could also be brought into this facility, and combined with the plutonium from pits. However, this could provide at most about a 20% masking, much of this material is too impure to be combined with clean pit plutonium if the plutonium is to be fabricated into MOX fuel, and DOE has already decided upon other pathways for disposition of this material.

Mixed Oxide Fuel Fabrication--Technology

The technology for the fabrication of MOX fuel is well known, as MOX fuel is in wide use in Europe and Japan as a means to close the nuclear fuel cycle, to realize energy value from plutonium remaining in spent fuel, and to reduce the volume of high level waste (fission products and higher actinides). Four companies have commercial technology for MOX fuel fabrication: Belgo-Nucleaire in Belgium, Cogema in France, British Nuclear Fuels, Limited in England, and Siemans in Germany.

The MOX fabrication process is similar for all the companies. Shown below is the fabrication process used by Los Alamos National Laboratory for MOX fuel for the Parallex experiment in a Canadian reactor. It is representative of the process used by others.



MOX Fuel Fabrication

Removal of gallium may be accomplished by baking plutonium oxide in a reducing atmosphere, as indicated, or the oxide may be produced through an aqueous process that would eliminate gallium as well as produce a precipitated powder. This is the process used throughout Europe for MOX fuel production.

The processing steps, through rod loading and welding, are all glovebox operations which may or may not be highly automated.

MOX Fuel Fabrication--Monitoring

As for pit disassembly and conversion, material accounting will be performed throughout the MOX fuel fabrication process. However, no material anywhere in the process is classified or contains data that must be protected. Therefore, many options can be offered for safeguarding the process. It is suggested that methods used by EURATOM and IAEA in the European facilities would be most appropriate for monitoring MOX fuel fabrication in the US--and Russian--disposition programs.