COMMENTARY

on

"We Need to Reprocess Spent Nuclear Fuel, and Can Do It Safely, at Reasonable Cost," by Clinton Bastin, *21st Century Science & Technology,* Summer 2008, pp. 10-20

by

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The title of Clinton Bastin's article states that nuclear reprocessing can be done safely and at reasonable cost—and we heartily agree. But the discussion misses a key point: Today there are better technologies than those debated and developed in the 1950s.

In an apparently dual-purpose article, Mr. Bastin argues two points. The first eight of the eleven pages, are expended on championing one specific processing technology from the '50s (Savannah River's variant of PUREX),[1] while panning another from the same period (the ICPP PUREX variant). In so doing, he gives an interesting history of the give-and-take among the various contractors working to develop an effective reprocessing technology—but that is not our focus. Since both of those technologies are outdated and hence irrelevant to fast-reactor decisions, we will concentrate on Bastin's second cause: his conviction that aqueous processing (PUREX) is superior to non-aqueous pyro-chemical processing ("pyro," for short) for recycling fast-reactor fuel.[2]

Before detailed comments, here are some general observations.

- In connection with the deployment of fast reactors, there are two rather distinct fuel-processing jobs. The first is to separate the used LWR fuel into three streams: fission products (waste), fast-reactor fuel (transuranics and some uranium), and the bulk of the uranium (to be stored for future use). For this job there are two principal candidates: UREX+ (an aqueous process derived from PUREX), and pyro-metallurgical processing ("pyro" for short; it's non-aqueous). The jury is still out on which of these will prevail. At present, the General Electric Company is proposing to use the latter for a commercial demonstration of its fast-reactor recycling technology.

  The second task is recycling the spent fuel from fast reactors. If the fuel is metallic (which has significant advantages over ceramic), pyro is the method of choice. But if the fuel is an oxide (or other ceramic), UREX+ would be preferable. Although he doesn't say so explicitly, we deduce that Mr. Bastin is an advocate of ceramic fast-reactor fuel.

- In 1999 the National Academy Press published a report by the National Research Council on a thorough and expert review of pyroprocessing, "Electrometallurgical Techniques for DOE Spent Fuel Treatment," which affirmed the technical practicality of pyroprocessing. Their finding: "The committee finds no technical barriers to the use of electrometallurgical technology to process the remainder of the EBR-II fuel." Their recommendation: "If the DOE wants an additional option besides PUREX for treating uranium oxide spent nuclear fuel, it should seriously consider continued developed and implementation of the lithium reduction step as a head-end process to EMT." [EMT = ElectroMetallurgical Treatment].

- Mr. Bastin's information regarding the state of the art of pyrometallurgical technology for treating reactor fuel seems to end as of 1991. Although the main program was discontinued in 1994, low-level development continued at General Electric, which now considers it ready for demonstration on a commercial scale.

- Pyroprocessing dramatically reduces the challenges of dealing with nuclear waste relative to PUREX type processes.

Bastin's case is summarized in the box on the penultimate page (p.19) of his article. What follows is a transcript of the text from that box, with comments interspersed.

Pyroprocessing and the Integral Fast Reactor: A Case Study of So-called Proliferation-Resistant Fuel

by Clinton Bastin

In 1991, I was assigned by DOE's Office of Nuclear Energy to develop criteria for evaluation of a planned demonstration of DOE's Integral Fast Reactor (IFR) "proliferation-resistant," "pyroprocess-based" fuel cycle. I visited DOE sites in Chicago and Idaho to inspect process equipment and details of planned demonstration operation, and learned that DOE plans were for a demonstration of a process, not technology, and that questions of operability, maintainability, safeguardability, and containment of radioactivity—major problems with commercial reprocessing—would not have been resolved.

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1 Clinton Bastin was the Program Manager at Savannah River for some years. It is reputed to have been a very well-run operation.

2 For a technical discussion of the merits of cycling plutonium back into thermal reactors, see G. S. Stanford, "LWR Recycle: Necessity or Impediment?" From the *Proceedings of Global 2003,* ANS Winter Meeting, New Orleans, November 16-20, 2003. http://www.nationalcenter.org/LWRStanford.pdf

That was Bastin's personal opinion, formed presumably in 1991. By 1994, when the IFR development program was terminated (for non-technical reasons), the technology had advanced appreciably, and would have been ready for a commercial demonstration after an estimated 2-3 years and $200-300M. As remarked above, GE continued work at a low level, and now declares itself ready to do a commercial demonstration.

> Of greatest concern were great difficulties for material balance measurements and high plutonium losses. These findings led to a conclusion that the safeguards challenge would be difficult and the process as planned would not be proliferation-resistant nor viable for commercial nuclear fuel recycle.

To repeat, it was a work in progress. That "conclusion" was Bastin's, and it has become clear that the concern about plutonium losses was misplaced: plutonium losses are now projected to be one percent or less. GE projects that IFRs with pyro recycling can be a fully competitive commercial operation. Both PUREX and pyro face safeguards challenges, for which the ultimate solutions are political rather than technical. The major concern for the Ford and Carter administrations was, and the proper concern still is, not the availability of the technology, but the control of the material produced by this technology.

> Concerns about the planned demonstration were reviewed with DOE and DOE laboratory management and technical staff without significant disagreement, . . .

We can't speak for the DOE, but there was vigorous disagreement on the part of the Laboratory's management and technical staff who were most familiar with the technology.

> . . . and are summarized here:

> (1) Processes to be used were similar to those used for plutonium metal processing in the Atomic Energy Commission weapon programs. Much greater difficulty was experienced in plutonium metal processing than in properly designed aqueous reprocessing. Large accumulations of scrap were normal at all plutonium metal plants, except for those at the Savannah River Plant where scrap was immediately redissolved and returned to reprocessing.

> In earlier, similar fuel cycle experiments, large amounts of scrap were shipped to the Idaho Chemical Processing Plant for recovery.

The requirements of a weapons program, where pure plutonium of high isotopic quality is needed, are very different from those of a fuel recycling program where neither chemical nor isotopic purity is wanted, or even desirable. The actinide content of IFR waste is minuscule—projected to be well under 10 kg per GWe-yr.

> (2) Equipment proposed for the DOE fuel cycle was much more complex than that used in aqueous reprocessing (the PUREX system) and would have been very difficult to maintain for reasonable on-stream time. In-situ manipulator-type maintenance would be needed. The rapid, remote equipment-replacement system used in successful reprocessing would not be appropriate.

As it been since the start of the IFR program, the promise of pyro lies in its compactness, its batch nature, and thus its ability to be deployed in much smaller sizes (and yet be economic, according to GE's estimates) than PUREX (or the aqueous processes COEX, UREX, or CIVEX, etc.). The need for in-situ manipulator-type maintenance is a proliferation-resistance advantage.

> (3) Material measurement in the electrorefiner was extremely difficult under cold, development conditions and was performed only about every year or two in the development facility. Measurement of fully irradiated fuel in a remote environment would be far more difficult; thus, material accountability and safeguards would be virtually impossible.

Accurate acountancy is indeed somewhat more complex than in an aqueous process, but there is reason to think that sufficiently accurate methods can be worked out. Offsetting the accounting problem is the relative ease of monitoring the process to detect illicit diversion. The fact is that all types of reprocessing facilities must be monitored to assure that they are not being misused.

> (4) High process losses (10-20 percent) were experienced, particularly in the fuel fabrication step, and high process losses would have been likely in electrorefining. This, combined with measurement difficulties, makes significant diversion detection impossible

Note the past conditional tense, "*would have been likely*." The worry about process losses has turned out to be unfounded.

> (5) Operations in a remote environment are about three times as difficult as operations in glove boxes; operations in an inert environment are similarly more difficult. The combination contemplated for the IFR fuel cycle might be ten times as difficult as those in glove boxes, or about three times as difficult as those in aqueous reprocessing, without consideration of the more complex equipment planned for the IFR process. High temperatures would further increase difficulties.

Those problems have been dealt with successfully on a laboratory scale. A commercial-scale demo is needed.

> (6) The IFR process requires use of exotic materials that are not available in forms/shapes needed. Research for materials was under way, but there was no experience base for use of these materials.

It's true that there are some aspects of electrochemical techniques yet to be established. For example, the Pu-minor actinide extractions need sustained attention, and mold and crucible materials are a major issue. These are problems to be addressed in the course of a commercial demonstration, and there is no reason to suspect any show-stoppers.

The compensating factors (vastly smaller quantities of material, tolerance of the fast reactor as to product purity, inherent self-protection features, on-site processing) give promise that, with appropriate safeguards, the process can be reduced to routine industrial practice.

We also note that PUREX had many sticky problems to be faced during its development, and they were eventually overcome—with many times more federal help than has come the way of pyroprocessing development. The IFR program was terminated in 1994, not because the technology seemed to be failing, but because it clearly was going to succeed.

(7) Inter-process transfer of nuclear materials requires physical movement of containers of nuclear material as opposed to transfer through piping in reprocessing plants that have operated successfully. The containers are not fully sealed. Thus, there is significant potential for release of contamination into the cell atmosphere.

Both PUREX and pyro have unique engineering problems. A PUREX vulnerability is that a clandestine tapping of a liquid transfer pipe to divert a small fraction of the plutonium flow might be hard for an inspector to spot. Also, pipes can spring leaks. The pilot pyrochemical plant at the EBR-II site has been working well for more than 12 years.

(8) Fissile plutonium is in weapons-usable form and in concentrations usable for a significant nuclear explosive. Some reviewers argued that in-process materials may not be directly usable for weapons suitable for military stockpiles, but clever operators of electrorefining equipment might be able to produce fairly pure plutonium metal directly usable for military type nuclear explosives.

In normal operation, a PUREX plant produces plutonium with the chemical purity needed for weapons This is not true of a pyro plant in normal operation. To get weapons material from a PUREX plant, all one has to do is input lightly irradiated fuel, with no major change in operating conditions. But with a pyro plant, even given lightly irradiated fuel, the output still has to be chemically separated by a subsequent PUREX-type process, easily spotted by inspectors.

The proliferation benefits of fast-reactor recycle are real: rapid denaturing of weapons-grade plutonium, ultimate elimination of the need for enrichment, no need for stocks of plutonium, no orphan used fuel but vastly increased motivation for inventory control of all nuclear fuel, and more.

The reality, however, is that any fuel-processing plant can be subverted to produce weapons-quality plutonium from lightly irradiated fuel, which is why there must be international oversight of processing as well as of enrichment.

(9) The requirement for inter-process transfer by physical movement by manipulators of containers of nuclear material instead of through pipes would limit applicability of the IFR fuel cycle process to research, or production of small amounts of plutonium. *—July 21, 2008*

The economy of scale is indeed larger for aqueous methods. Pyroprocessing is inherently a batch process, suitable for on-site collocation with the reactors it services. With such collocation, there is no need for off-site shipment of actinides. Once they enter the plant, they stay there—which minimizes commerce in plutonium, and helps with the accountancy problem. Analysts at General Electric predict an economically competitive power cost with commercialized IFR/pyro installations.

Conclusion. While some engineering aspects are yet to be resolved, there are no obvious show-stoppers on the path to commercial pyro recycling with metal-fueled fast reactors.