What Is the IFR?

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by

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Note by author: The original version was written in the late 1990s—and not much has changed since. IFRs are discussed in the context of today's nuclear fuel, which is uranium. There are those who point out, correctly, that thorium too is exploitable as a fuel for fission reactors. However, comparison of the demonstrated properties of IFRs with the reasonable but thus-far hypothetical capabilities of thorium-based reactors is a topic for a different occasion. *May2013*

What is the IFR?

The IFR is a potential provider of safe, abundant, non-polluting power.

IFR stands for ***Integral Fast Reactor***. It is a power-reactor-development program, based on a revolutionary concept for generating nuclear power—not only a new type of reactor, but an entire new nuclear fuel cycle. The reactor part of that fuel cycle was called the ALMR—Advanced Liquid Metal Reactor. In what many see as an ill-conceived move, proof-of-concept research on the IFR/ALMR was discontinued by the U.S. government in 1994, only three years before completion.

You might also see references to the AFR, which stands for "Advanced Fast Reactor." It's a concept very similar to the ALMR, with some improvements thrown in. GE-Hitachi has the plans for a commercial version they call PRISM.[1]

How was the IFR idea different from the concepts underlying traditional nuclear-power fuel cycles?

All of those fuel cycles were derived from technologies developed to meet special military needs: naval propulsion, uranium enrichment, weapons-plutonium production, and plutonium separation. Waste disposal has been approached as "someone else's problem." The IFR concept is directed strictly to meeting the needs of civilian power generation. It is an integrated, weapons-incompatible, proliferation-resistant cycle that is "closed"—it encompasses the entire fuel cycle, including fuel production and fabrication, power generation, reprocessing and waste management.

Do we need a new kind of reactor? What's wrong with what we have now?

IFRs could reduce or eliminate significant difficulties that beset thermal-reactor fuel cycles—problems or concerns with:

* production and build-up of plutonium
* short-term management of plutonium
* long-term management of plutonium
* plutonium in national and international commerce
* other proliferation concerns
* long-term waste management
* environmental effects
* resource conservation
* long-term energy supply
* safety

What is a fuel cycle? What fuel cycles are there?

"Fuel cycle" refers to all the steps involving nuclear fuel that are needed to generate electricity: mining, milling, enrichment, fuel fabrication, reactor operation, reprocessing and waste management. Depending on the fuel cycle, some of those steps might not be needed. The three major fuel cycles of current interest are: thermal without reprocessing ("once-through," or "throw-away"), thermal with reprocessing, and fast reactors—e.g. IFR. The IFR will eliminate the need for uranium mining (for centuries), and milling and enrichment (forever).

Who was working on the IFR? How far along was it?

The idea of the IFR originated at Argonne National Laboratory. When the project was aborted, they were about three years from finishing a study that was expected to establish firmly the technical and economic practicality of the concept. Progress had been spectacular. Design of the ALMR was being done at General Electric in San Jose, California. Construction of a full-size prototype was expected when Argonne's research study had been completed and a current need had been demonstrated.

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[1] PRISM: Power Reactor Innovative Small Module.

What sort of reactor was the ALMR?

The ALMR was to be a "fast" reactor (one in which the chain reaction is maintained by high-energy neutrons)—so called because the energy spectrum of the neutrons is said to be fast.

Is there a slow reactor?

Yes, in concept, but it's not called "slow," it's called "thermal." Almost exclusively, current reactors are of the thermal variety: their chain reaction relies on thermal (slow) neutrons. In most of the thermal-spectrum reactors, the neutrons are moderated (slowed) by light water. Such reactors are called LWRs.

What is the most important difference in capabilities?

Probably this one: Inherently, thermal reactors are copious producers of plutonium, which is currently regarded as a white elephant to be gotten rid of, while IFRs remove plutonium from the waste stream and use it as a vital ingredient in the reactor's fuel.

What's so important about plutonium?

High-quality plutonium is the preferred bomb material for a sophisticated nuclear weapons program. It is even possible to make a crude nuclear explosive with low-quality plutonium, such as is found in power reactors.

However, although it's not widely appreciated, the most important thing about plutonium is that it's the essential key to releasing the vast store of energy that now is locked up in the uranium that has already been mined.

What else can IFRs use for fuel, besides plutonium?

The basic fuel for IFRs is uranium. Plutonium serves as a sort of catalyst that permits uranium's energy to be accessed. The IFR's fast spectrum permits it to burn any and all actinides from thorium on up. This is because in a fast neutron spectrum there are enough extra neutrons to convert the actinide isotopes that don't fission easily into ones that do. The most important actinide elements are uranium (atomic number 92), plutonium (94) and, to a lesser extent, thorium (90). Since currently there is a glut of plutonium continuing to pile up from nuclear weapons and from thermal-reactor operations worldwide, the first IFRs will undoubtedly be fueled primarily with some of that plutonium.

How is that different from thermal reactors?

In a thermal neutron spectrum, many of the fission products and actinide isotopes absorb neutrons readily without undergoing fission (they have a high "capture cross section"), and the chain reaction is "poisoned" if too much of such material is present. Thus a thermal reactor fueled with uranium cannot be a net burner of transuranic actinides.[2] The main starting fuel for thermal reactors is a mixture of the fissile isotope U-235 (Pu-239 can also be used), along with the fertile isotope U-238.

What in the world are "transuranic actinides?"

They are the elements beyond uranium—that is, their atomic number is 93 or greater: neptunium, plutonium, americium, curium, and more. All of them are man-made elements, since they are so radioactive that the naturally created ones have long since decayed away in our little bit of the universe. They are also called "higher actinides."

And what do you mean by "fissile" and "fertile?"

An isotope is called "fertile" when the addition of a neutron changes it into a fissile isotope—one that, like U-235, has a very high probability of undergoing fission when exposed to thermal neutrons. Both fissile and fertile isotopes are fissionable—it's just that fertile ones require a high-energy neutron to make them split.

Burning and Breeding

What is a "breeder?"

A breeder is a reactor that is configured so as to produce more fissile material than it consumes. A fast reactor can be designed and operated to be either a net breeder or a net burner. A thermal reactor is a net burner of nuclear fuel, but—and this is very important—all uranium-fueled thermal reactors are prolific breeders of plutonium.

What do you mean?

A thermal reactor starts out with no plutonium at all, and soon has a lot of it, created when neutrons are absorbed by U-238, which leads to Pu-239. In the process, though, it burns more fuel (mainly uranium) than it gives back as plutonium, and therefore is not called a breeder.

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[2] There are claims that future thorium-fueled reactors could also burn the higher actinides.

If IFRs can be either breeders or burners, why do some people insist on calling them breeders?

Partly for historical reasons (originally, fast reactors were investigated because of their potential to breed), partly because of genuine confusion, and partly for emotional impact, since "breeder" carries the subliminal connotation of runaway plutonium production. The central fact that those people are missing is that with IFRs you can choose not to breed plutonium, whereas with thermal reactors you make plutonium whether you want it or not.

Then it is today's reactors that are runaway producers of plutonium, and IFRs could put a stop to it.

Exactly.

What about the high-grade plutonium from dismantled nuclear weapons? Can we get rid of it?

Depends on what you mean by "get rid of it." I suppose you could say we would be rid of it if it were degraded to the point where it is as hard to deal with as the poor-quality plutonium in the used fuel from thermal reactors. That's called the "spent fuel standard" for disposition of weapons plutonium.

How do you do that?

One straightforward way is to incorporate it in fuel for today's thermal reactors. The fuel would consist of a mixture of the oxides of uranium and plutonium, called MOX. That process is now being started in the U.S. and Russia.

How long will it take?

There's maybe 200 metric tonnes (1 metric ton equaling 1.1 standard tons) of weapons-grade plutonium in the world, most of which, we hope, will gradually become available for disposal over the next two or three decades. To process that much plutonium in 30 MOX-burning thermal-reactor plants (size 1000 MWe) would take approximately 20 years. Thus the MOX approach should be able to deal satisfactorily with the weapons plutonium.

Can IFRs help with this?

Eventually, when we get IFRs. When they do start up, they will of course begin using the accumulated plutonium —weapons-grade first, probably, if there's any left, and then reactor-grade.

In fact, the plutonium now in the U.S. inventory of "waste" (used fuel) from LWRs could be used to start up about 80 large IFRs (1,000 megawatts-electrical each), which would safely segregate the entire plutonium inventory. And the unused uranium in that used fuel could keep those 80 IFRs (and their successors) running for perhaps 1,000 years, generating electricity and bringing in revenue.

Commerce in Plutonium

You explained why the IFR is "fast." Now, why is it "integral?"

"Integral" refers to the fact that the fuel processing facility can be an integral part of the IFR plant.

Is that important?

Very, if you are concerned about shipments of plutonium and spent fuel, or if you want to minimize national and international commerce in plutonium.

I think it is U.S. policy to discourage commerce in plutonium.

Yes, it is. And these days there certainly is commerce in plutonium—witness the controversy over shipments of plutonium from France to Japan a few years ago, and the recent controversy in England over a reprocessing plant at Sellafield. For the foreseeable future, and beyond, there will be no plutonium shipped out of IFR plants. The only shipments will be into them, from dismantled weapons and thermal reactors. Those are not extra shipments, but ones that otherwise would be going to repositories. Thus the IFR all but eliminates commerce in plutonium.

How can that be?

At first, IFR plants will probably be "sinks" for plutonium: plutonium to be disposed of is shipped in, and there it is consumed, with on-site recycling as needed. Only trace amounts ever come out.

Later on, when more fissile material is needed for starting up new IFRs, they will be used as breeders. At that point, there will be a one-time set of fuel shipments to each new IFR, and that's it. From then on, only small shipments (about one ton per year) of unenriched uranium will be required.

Safety

How safe are IFRs?

While the safety record of commercial reactors of Western design is superb, Three Mile Island notwithstanding, it would be desirable to have reactors that rely more on inherent safety features and less on engineered ones. ALMRs do that.

What is an "inherent safety feature?"

A safety mechanism that does not depend on human or mechanical intervention. For instance, ALMRs use metallic fuel rods, whereas LWRs use oxide fuel (as the Clinch River Breeder Reactor [CRBR] would have done).

Why are metallic fuel rods an inherent safety feature?

Metal is a good heat conductor, while oxide is a poor one. That means the interiors of the metal rods stay much cooler, which means that there is far less heat stored in an operating ALMR, which means that if there were a loss of coolant flow there would be much less heat present to raise the temperature of the fuel, which means that the consequences of a hypothetical accident would be much less severe.

Why is that?

Briefly, there's a phenomenon called the "resonance Doppler effect," which causes the reactivity to change somewhat with temperature. Because in an ALMR the temperature does not change much in a hypothetical accident, the reactor is much more stable. Also, in the event of an unplanned shutdown, there is less stored heat to cause fuel to melt.

O.K. What else?

ALMRs use liquid sodium for cooling and heat transfer, which makes the system intrinsically safer than one that uses water. That is because the molten sodium runs at atmospheric pressure, which means that there is no internal pressure to cause the type of accident that has to be carefully designed against in an LWR: a massive pipe rupture followed by "blowdown" of the coolant when the loss of pressure lets it the water flash into steam.

Also, sodium is not corrosive like water is.

But doesn't sodium burn in air and react violently with water?

Yes it does, and this of course requires prudent design, involving inert atmospheres and multiple barriers.

Not so fast! Seems to me there was a serious sodium leak and fire at a Japanese fast reactor.

You're right. In December 1995, at the Monju reactor, a temperature sensor broke and sodium leaked from a secondary sodium loop and caught fire. The plant was shut down. It was repaired within a year or so, but its restart has been held up ever since by a series of non-technical problems.

How many people were hurt?

None.

Was radioactivity released?

No.

Was the reactor damaged?

No.

Was there any damage at all?

Yes. Some minor damage was caused by the burning sodium, and combustion products were spread through a portion of the building; cleaning them up took almost a year. The accident was classified as Category 1 on the international scale of 0 to 7 (with 0 being the least serious) by a committee of independent specialists.

So the sodium isn't so safe after all.

When you think about it, it is pretty safe. There have been sodium fires, and undoubtedly there will be more. The Monju fire was a public-relations disaster, but did not even come close to being a threat to public health. There is a great deal of industrial experience with liquid sodium, and there have been very few problems.

No serious accidents?

The worst sodium accident I know about happened in 1986 at Almeria, Spain. It was in a solar (not nuclear) power plant, where a pipe carrying liquid sodium burst, injuring several workers and destroying the power plant.

However, it that case the accident was much worse than could happen in an IFR, because the sodium was under high pressure (5 atmospheres), whereas in a reactor the sodium would not be pressurized.

Well, I suppose the sodium is a risk we can tolerate, since we need electricity.

I think so.

What's become of the Monju reactor?

Last I heard, it had commenced initial operations in May 2010, after a string of administrative and other non-technical snafus. For a while it was scheduled to go on the grid in 2013, but the Fukushima incident has led to a change in the Japanese attitude towards nuclear power, so its still up in the air.

We were talking about inherent safety features. Are there any others?

The ALMR core sits in a pool of liquid sodium. In combination with the low heat content of the metal fuel rods, this means that, if there were to be loss of control power, the core would be cooled passively by convection.

Is this different than for other liquid-metal-cooled reactors?

Almost all the earlier fast reactors were of the "loop type"—relying more heavily on forced coolant flow—and also their oxide fuel makes passive cooling more problematic.

Wasn't passive cooling tested in a prototype ALMR?

Yes, it was. All control power for the operating reactor was cut off. Coolant pumps stopped, control rods did not move, and the operators did nothing. The core temperature rose slightly, causing the reactor to go subcritical and shut itself down without incident. Unassisted convective cooling then prevented overheating.

Conservation and the Environment

What are the environmental considerations?

We already mentioned waste management. In addition, it can be argued that the major environmental problems with nuclear power are the consequences of the mining and milling operations. Because IFRs can use not only the surplus plutonium, but also the uranium (including U-238) that has already been mined and milled, they can eliminate for centuries any further need for mining or milling.

And of course, in common with all nuclear reactors, operating IFRs emit no carbon dioxide.

Do they put out any atmospheric pollutants?

None worth mentioning.

Then there some that aren't worth mentioning?

Extremely small amounts of radioactive gas.

How small?

So small that there's a lot more radioactivity from coal-burning plants.

You're pulling my leg.

No I'm not. In coal there are trace amounts of radium and uranium, for instance, that come out of the smokestacks.

Then there's dangerous radiation from coal plants?

No, there isn't—it's far below natural background levels. But nuclear plants put out even less.

Then I won't worry. How do IFRs help conserve natural resources?

Thermal reactors are incredibly profligate with the earth's endowment of potential nuclear fuel. The once-through, "throw-away" cycle in favor in the U.S. uses less than a hundredth of the energy potential of the mined uranium. Even with recycle, as in France, scarcely more than 1% can be extracted. IFRs can use almost all of it.

Wait a minute—less than 1% with recycle in thermal reactors? I thought you could get nearly all of the energy that way.

Sorry, but you can't. After one or two passes through a reactor, the plutonium has gotten so contaminated with isotopes heavier than Pu-239 that various technical and operational problems arise. Moreover, almost all the used uranium goes into long-term storage. The only well-established way to consume all of it is in a flux of fast neutrons.

I'll be darned! Well anyway, with uranium so cheap, why do we care about using it efficiently?

Well, the uranium reserves are probably adequate for fueling our profligate thermal reactors for several decades at least, so conserving the resource is not an immediate concern. But even with no shortage of uranium, the IFR's breeding ability and its hundred-fold gain in resource utilization are very important, because the more urgent concerns are related to weapons proliferation, waste disposal, and environmental degradation.

You already mentioned those.

Yes, but there's more to be said, especially about proliferation. For one thing, the spread of LWRs means the concomitant spread of the capacity to enrich uranium—and the easiest route to nuclear weapons is via enriched uranium, not plutonium. Therefore the arms-control community is particularly interested in seeing to it that the enrichment facilities are limited to safe locations under effective international supervision. The more LWRs there are, the harder that task becomes.

What else?

Technological leadership. In aborting the IFR program in 1994, the United States abdicated its role as the leader in the technology of nuclear power. Inevitably, the rest of the world is leaving us in the dust. Other nations—India, China, Japan, more—are developing their own brands of fast reactors, along with the needed fuel-processing facilities. If we want to be able to influence safe the spread of nuclear technology, we will rapidly do a commercial-scale demonstration of the superior IFR technology, including pyroprocessing of the fuel, and share the technology—with appropriate safeguards.

Reprocessing & Proliferation

Wouldn't thermal reactors with reprocessing be more efficient than the once-through cycle?

Yes, but only a little. Recycling (it would be with the PUREX process, or an equivalent) can only increase the resource utilization by 20 or 30 percent, still leaving unused about 99 percent of the energy in the mined uranium. And remember the consequences: growing stockpiles of plutonium, pure plutonium streams in the PUREX plants, and the creation of 100,000-year plutonium mines.

If you're going to talk about "PUREX" and "pyroprocessing" and "plutonium mines" you should say what they are. First, what's PUREX?

It's a chemical process developed for the nuclear weapons program, to separate plutonium from everything else that comes out of a reactor. Weapons require very pure plutonium, and that's what PUREX delivers. The ***pyroprocess*** used in the IFR is very different. It not only does not, it cannot, produce plutonium with the chemical purity needed for weapons.

O.k., and you can skip the detailed chemistry. But why do you keep referring to chemical purity?

Because chemical and isotopic quality are two different things. Plutonium for a weapon has to be pure chemically, and weapons designers also want good isotopic quality—that is, they want at least 93% of their plutonium to consist of the isotope Pu-239. A chemical process does not separate isotopes.

I see. Now, what about the "plutonium mines?"

When spent fuel or vitrified reprocessing waste from thermal reactors is buried, the result is a concentrated geological deposit of plutonium. As its radioactivity decays, those deposits are sources of raw material for weapons, becoming increasingly attractive over the next 100,000 years and more (the half-life of Pu-239 being 24,000 years).

You listed, back at the beginning, some problems that the IFR would ameliorate. A lot of those problems are obviously related to proliferation of nuclear weapons.

Definitely. For instance, although thermal reactors consume more fuel than they produce, and thus are not called "breeders," they inescapably create a lot of plutonium, as I said. And that poses serious concerns about nuclear proliferation. And proliferation concerns are even greater when fuel from thermal reactors is recycled, since the PUREX method is used. IFRs have neither of those drawbacks.

Why does it seem that there is more proliferation-related concern about plutonium than about uranium? Can't you make bombs from either?

Yes. The best isotopes for nuclear explosives are U-235, Pu-239, and U-233. Only the first two of those, however, have been widely used. All the other actinide isotopes, if present in appreciable quantity, in one way or another complicate the design and construction of bombs and degrade their performance. Adequate isotopic purity is therefore important, and isotopic separation is much more difficult than chemical separation. Even so, with plutonium of almost any isotopic composition it is technically possible to make an explosive (although designers of military weapons demand plutonium that is at least 93% Pu-239), whereas if U-235 is sufficiently diluted with U-238 (which is easy to do and hard to undo), the mixture cannot be used for a bomb.

High-quality plutonium is the material of choice for a large and sophisticated nuclear arsenal, but highly enriched uranium would be the easiest route to a few elementary nuclear explosives. That's why it's important to minimize the need for enrichment facilities.

So why the emphasis on plutonium?

You're asking me to read people's minds, and I'm not good at that. Both uranium and plutonium are of proliferation concern.

Where is the best place for plutonium?

Where better than in a reactor plant—particularly an IFR facility, where there is never pure plutonium (except some, briefly, when it comes in from dismantled weapons), where the radioactivity levels are lethal, and where the operations are done remotely under an inert, smothering atmosphere? Once enough IFRs are deployed, there will hardly ever be any need to have plutonium outside a reactor plant..

How does the IFR square with U.S. policy of discouraging plutonium production, reprocessing and use?

It is entirely consistent with the intent of that policy—namely, to render plutonium as inaccessible for weapons use as possible. The wording of the policy, however, is now obsolete.

How so?

It was formulated before the IFR's pyroprocessing technology was known—when "reprocessing" was synonymous with PUREX, which creates plutonium of the chemical purity needed for weapons. Since now there is a fuel cycle that promises to provide far-superior management of plutonium, the policy has been overtaken by events.

Why is the IFR better than PUREX? Doesn't "recycling" mean separation of plutonium, regardless of the method?

No, not in the IFR—and that misunderstanding accounts for some of the opposition. The IFR's pyroprocessing and electrorefining method is not capable of making plutonium that is pure enough for weapons. If a proliferator were to start with IFR material, he or she would have to employ an extra chemical separation step.

But there is plutonium in IFRs, along with other fissionable isotopes. Seems to me that a proliferator could take some of that and make a bomb.

Some people do say that, but they're wrong, according to expert bomb designers at Livermore National Laboratory. They looked at the problem in detail, and concluded that plutonium-bearing material taken from anywhere in the IFR cycle was so ornery, because of inherent heat, radioactivity and spontaneous neutrons, that making a bomb with it without chemical separation of the plutonium would be essentially impossible—far, far harder than using today's reactor-grade plutonium.

So? Why wouldn't they use chemical separation?

First of all, they would need a PUREX-type plant—something that does not exist in the IFR cycle.

Second, the input material is so fiendishly radioactive that the processing facility would have to be more elaborate than any PUREX plant now in existence. The operations would have to be done entirely by remote control, behind heavy shielding, or the operators would die before getting the job done. The installation would cost millions, and would be very hard to conceal.

Third, a routine safeguards regime would readily spot any such modification to an IFR plant, or diversion of highly radioactive material beyond the plant.

Fourth, of all the ways there are to get plutonium—of any isotopic quality—this is probably the all-time, hands-down hardest.

The Long Term

Does the plutonium now existing and being produced by thermal reactors raise any proliferation concerns for the long term?

It certainly does. As I said earlier, burying the spent fuel from today's thermal reactors creates geological deposits of plutonium whose desirability for weapons use is continually improving. Some 30 countries now have thermal-reactor programs, and the number will grow. To conceive of that many custodial programs being maintained effectively for millennia is a challenge to the imagination. Since the IFR can immobilize and consume plutonium, it can completely eliminate this long-term concern.

Are there other waste-disposal problems that could be lessened?

Yes. Some constituents of the waste from thermal reactors remain appreciably radioactive for thousands of years, leading to a court-ordered million-year stability criterion for disposal sites. Waste disposal would be simpler if that time frame could be shortened. With IFR waste, the time of concern is less than 500 years.

What about a 1994 report by the National Academy of Sciences? The Washington Post said that the NAS report "denounces the idea of building new reactors to consume plutonium."

That characterization of the report is a little strong, but it is true that the members of the NAS committee seem not to have been familiar with the plutonium-management potential of the IFR. They did, however, recognize the "plutonium mine" problem. They say (Executive Summary, p.3):

> "Because plutonium in spent fuel or glass logs incorporating high-level wastes still entails a risk of weapons use, and because the barrier to such use diminishes with time as the radioactivity decays, consideration of further steps to reduce the long-term proliferation risks of such materials is required, regardless of what option is chosen for [near-term] disposition of weapons plutonium. *This global effort should include continued consideration of more proliferation-resistant nuclear fuel cycles, including concepts that might offer a long-term option for nearly complete elimination of the world's plutonium stocks*." [Emphasis added.]

The IFR, obviously, is just such a fuel cycle—a prime candidate for "continued consideration."

Safeguards

You mentioned safeguards a while ago. Are you saying that IFRs need to be safeguarded?

Of course. Any kind of nuclear fuel cycle needs safeguards procedures, the most important job being to make sure that a power reactor is not operated so as to produce high-quality plutonium. The IFR is no exception, although it might be more easily safeguarded than other cycles.

Are there now any reactors that are not safeguarded?

Unfortunately, yes. A number of countries, such as India, Pakistan, and Israel, have not yet signed the Nuclear Non-Proliferation Treaty and do not permit all of their reactors to be inspected by the IAEA (International Atomic Energy Agency).

Why should there be IFRs if a country could expel the inspectors and make bombs?

Because a country could do that with any kind of reactor, and overall the IFR is by far the most proliferation-resistant nuclear fuel cycle.

Better than the thermal-reactor throw-away cycle?

Near-term, it's comparable—quite possibly better. But when you factor in the long term (no plutonium mines), it's the clear winner. And the IFR is far better than anything involving PUREX—which will inevitably spread to more countries, unless they go to IFR-type reactors.

Has a bomb ever been made that used reactor plutonium?

That is unclear. A U.S. weapons lab conducted an explosion in 1962 that made use of what was stated to be "reactor-grade plutonium," the definition of which was different in 1962. While the details of that test and its results are still classified, some of the difficulties that would be encountered in making a weapon composed of reactor-grade plutonium are formidable and predictable. Dr. Peter Jones, who was Director of the Aldermaston weapons research establishment in England when they too tested some low-grade material, says the job is extremely difficult. We do know that, even with sophisticated weapons design, the explosive yield would be seriously degraded.

But suppose a country wanted to make some plutonium bombs, and had nothing but an IFR?

If their IFR plants were safeguarded, the material in the processing stream would be highly undesirable, as I explained earlier, and their chances of diverting it undetected would be slim indeed. If not safeguarded, they could do what they could do with any other reactor—operate it on a special cycle to produce good quality weapons material. But in either case, most likely they would do what everyone else has done: construct a special production facility, including a PUREX plant. Detecting such a clandestine facility is probably the main, immediate challenge facing international safeguards, and has nothing to do with whether a country has IFRs or LWRs.

But the uranium route to a simple bomb is so much easier that that's probably the way a wannabe nuclear power would start out.

The Downside

There must be a downside. What is the single best technical argument against the IFR?

Isotopic composition of the plutonium. This is a very weak argument, but it is probably the only one with any technical validity. (There are arguments, largely nontechnical, about whether the IFR is needed or whether it would be economical.)

How does that isotopic argument go?

In outline, like this: Although it is technically possible, with difficulty, to make an explosive with plutonium of almost any isotopic composition, designers of military weapons demand plutonium that is at least 93% Pu-239. Plutonium from LWR spent fuel runs around 60% or less Pu-239, while that from IFRs tends to be in the 70-80% range, and thus is somewhat closer to what weapons designers want.

Why isn't that a forceful argument?

First, isotopic contamination is only one of many obstacles between a proliferator and a weapon from IFR fuel. I mentioned some of them a while back.

Second, having material that is 80% Pu-239 instead of 60% does not greatly lessen the difficulty of designing and building a bomb.

Third, and most important, remember that there are far easier ways to get fissile material for weapons—high quality material, at that—than from spent reactor fuel. Iraq, for instance, chose uranium enrichment. No country has ever used reactor-grade plutonium to make weapons for its arsenal.

Strongest Point

You mentioned the best argument against the IFR. What is the best argument for it?

Proliferation prevention. Near-term, the IFR makes PUREX illegitimate and plutonium inaccessible. Long term, it relieves future generations of the responsibility to guard the plutonium mines, and of the risks of not guarding them adequately.

There's another huge benefit, of course. If nothing better comes along, the IFR can supply the world with pollution-free energy for as long as civilization lasts. Uranium becomes just as inexhaustible as energy from the wind or sun.

But the waste problem seems to be uppermost in people's minds.

Yes it does, although it's really of secondary importance. The IFR's ability to solve that problem is the advantage that seems to impress the most people.

Since the IFR has so much going for it, development should be steaming full speed ahead, right?

Wouldn't you think so? Nevertheless, at the Clinton administration's urging, Congress terminated the research on October 1, 1994. The Senate voted to continue it, but the House prevailed in conference.

Well, I suppose at least we saved some of the taxpayers' money.

Wrong again. Termination cost as much over the ensuing four years as finishing the research would have done, especially since the Japanese were all set to chip in $60 million.

You're kidding. Why would our government do what it did?

Combination of factors, but the main one is plain misunderstanding of the facts I have just explained to you. Well-meaning but ill-informed people claiming to be experts confused pyroprocessing with PUREX, and convinced so many administrators and legislators that the IFR was a proliferation threat that the project was killed.

Isn't it time to revive it?

I think it is. Other countries are working on their own fast-reactor designs—inferior, in my opinion, but this country abandoned its technological lead in 1994.

What should we do to get that lead back?

Revitalize our nuclear R&D, and establish definitively the IFR's technical and commercial viability. To do that, all we need is one or two commercial-scale demonstration plants to finalize the details of the pyroprocessing techniques and to permit a better estimate of the probable cost of energy from production-model IFR plants. We should get moving.

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