PLENTIFUL ENERGY AND THE IFR STORY
by
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Adapted from a series of four articles, entitled
“Plentiful Energy, the IFR Story, and Related Matters,”
in THE REPUBLIC News and Issues Magazine,
June-September 2005

Abstract: The Integral Fast Reactor (IFR) was a concept that promised inexhaustible, clean, safe, proliferation-resistant energy, with waste that needed isolation for only hundreds of years rather than tens of thousands. The development of the IFR was abandoned by the U. S. government in 1994, as it neared completion, because too many in the U.S. Congress and Administration did not understand its potential to help control the spread of nuclear weapons. Nevertheless the deployment of a fast-fission technology with the general characteristics of the IFR is inevitable because the growing global demand for clean energy cannot be satisfied by today’s thermal reactors.

Keywords: clean energy; electorefining; fast fission; fast reactor; IFR; inexhaustible energy; nuclear power; nuclear waste; proliferation; proliferation-resistant; pyrochemical; pyrometallurgy; pyroprocessing; thermal reactor.

Biographical notes: Charles Till, now retired, was the long-time director of nuclear power reactor development at Argonne National Laboratory. Born and educated in Canada, he did graduate work at Imperial College, University of London, where he was granted a PhD in Nuclear Engineering with a specialty in Reactor Physics. Later still, he received an MBA from the University of Chicago. In a long career in research and development, he worked on each of the principal reactor types later commercialized and in use around the world. However, his principal interest was the fast-spectrum reactor, and in particular, in the last decades of his career, the development work that grew into the Integral Fast Reactor program.

Preface: Dr. Till was the long-time director of civilian nuclear power reactor development at Argonne National Laboratory. This program, by far the largest in the nation in the last decades of the century, was devoted entirely to research and development of nuclear reactors for electrical power generation. About two thousand engineers, scientists and supporting staff, along with a large complex of the facilities required for such work, were under his direction and guidance. For ten years, from 1984 to 1994, the work of this large team was focused exclusively on development of an Argonne brain-child, the Integral Fast Reactor. This technology promised an inherently safer reactor, a shorter-lived waste, and a limitless fuel supply.

Terry Robinson, THE REPUBLIC News and Issues Magazine
PART ONE: THE INTEGRAL FAST REACTOR

In the decade from 1984 to 1994, scientists at Argonne National Laboratory developed an advanced technology that promised safe nuclear power unlimited by fuel supplies, with a waste product sharply reduced both in radioactive lifetime and amount. The program, called the IFR, was cancelled suddenly in 1994, before the technology could be perfected in every detail. Its story is not widely known, nor are its implications widely appreciated. It is a story well worth telling.

The Integral Fast Reactor, or IFR, was a developmental program for a new nuclear power technology, one with very desirable characteristics not possessed by the current generation of nuclear reactors. The work was done at Argonne National Laboratory, just outside Chicago, and at Argonne’s large reactor development facilities in the desert in southeastern Idaho.

Taken together, the characteristics of this new technology amounted to a revolutionary improvement in the prospects for nuclear power for the generation of electricity in the massive amounts necessary in the future. It held out the possibility of revolutionary improvement in literally all the important areas of nuclear power: fuel efficiency, safety, waste, and non-proliferation characteristics.

The name Integral Fast Reactor described the principal characteristics of the technology: the word Integral was chosen to denote the fact that every element of a complete nuclear power system was being developed simultaneously, and each was an integral part of the whole. The reactor itself, the processes for treatment of the spent fuel as it is replaced by new fuel, the fabrication of the new fuel, and the treatment of the waste to put it in final form suitable for disposal—all were an integral part of the development and the product. Nothing was to be left behind to be developed later. No detail was to be left hanging, unresolved, to raise problems later, as had been the case in present generation of nuclear power. (The word Fast simply denotes technical characteristics of the neutrons in reactor operation, useful to know but not central to this discussion.)

The new safety characteristics of the reactor can be summarized by the phrases “inherently safe,” or “passively safe,” and both have been used in descriptions of the technology. The central point is that the reactor responds to any event that could lead to any significant accident by lowering reactor power to safe levels, right up to complete shutdown if necessary, without the need for any operator action, or indeed for any device at all to work—the reactor responds this way inherently, just due to materials used in its construction. Passive, then, denotes the fact that no movement of control rods, or any other mechanical device, is needed, nor is any action by the operators: the reactor responds to trouble passively, simply taking it in stride.

These safety characteristics were made possible by the development of a new type of fuel for the IFR, a metallic alloy, which, along with a liquid metal for coolant, made the reactor invulnerable to the most serious accidents that can befall a reactor. There are two of these, and both types have actually happened—one at Three Mile Island (Pennsylvania) in 1979, and the other at Chernobyl (Ukraine) in 1986.

Amazingly, about a month before the Chernobyl accident, Argonne scientists had performed two remarkable demonstrations on their IFR test reactor in Idaho. An invited international audience watched the IFR quietly shut down under accident conditions without any damage whatsoever. The first demonstration was precisely that of a Chernobyl-type accident as it might occur in an IFR. Then, on the same day, the exact conditions of the Three Mile Island accident were duplicated, again with a quiet, damage-free shutdown.

When the actual Chernobyl accident occurred, an alert science reporter for the Wall Street Journal, Jerry Bishop, a man with a long history of reportage on nuclear power development, recognized the importance of the Idaho demonstration. His article in the Journal caused a sudden increase in Congressional support for the IFR, and enabled its developers to accelerate the pace and widen the scope of IFR development.

The new fuel type also allowed new technology for processing the used fuel to cycle it back into the reactor. This gave huge benefits. It enabled the used fuel to be cleaned up and used again and again, extending fuel supplies more than a hundred-fold—and, extremely important, it made the lifetime of the radioactive waste much, much shorter, and a very much smaller volume as well. Because the fuel is metal, the process uses an extension of an electorefining process that is in common use in the metal-refining industries. The IFR process had a further advantage in that an installation
was small and cheap to implement. (Present methods of reprocessing require huge plants that cost billions of dollars to construct.)

The final benefit from IFR fuel and fuel processing lies in the fuel itself as it comes from the refining process. The methods of reprocessing commercial nuclear fuel in current use in several nations (but not in the US) were developed originally to provide very pure plutonium for use in nuclear weapons. The commercial plants have that same capability.

The IFR process, on the other hand, provided a fuel form with many different materials in it—next to useless for weapons purposes, but ideal as a fuel material. The process cannot purify plutonium from the IFR spent fuel—it is scientifically impossible for it to do so. The IFR technology should not contribute to weapons proliferation. On the contrary, if it replaces the present methods it should substantially reduce such risks.

The IFR refining process also produces a waste with less volume and a shortened radioactive life. The materials that are carried along in the fuel that ruin its value for weapons are the very ones that give current

nuclear “waste” (more accurately, used fuel) its long-lived radioactivity. But because they remain in the fuel throughout, they are burned up when recycled back into the reactor, and do not appear in the waste in any significant amount. The reduction in radioactive lifetime is dramatic—from tens of thousands of years down to a few hundred at most. And the IFR program included the development and proof testing of very stable, inert waste forms for final disposal.

As the discussion above starts to make clear, the IFR technology was one in which all the pieces fitted together, dovetailing to make each part of the system complement the rest, and to make possible an entire system that could have had a truly revolutionary impact on nuclear power for the future. The implications of its termination on energy supplies for the future are plainly and painfully obvious. This was to be no small marginal supplier of energy—it dealt with entire electrical energy needs of nations.

Its development was terminated and its personnel and facilities scattered to the winds. Reviving that option will be a challenge, but doing so is vital for a safe and reliable long-term supply of energy for the world.

PART TWO: THE ALTERNATIVE ENERGY SOURCES

In Part One we looked briefly at the history of nuclear power and the attributes of an advanced nuclear reactor system that appeared to promise substantial improvements over present reactors, but whose development was terminated a decade ago.

Now we look at the questions, “Do we really want nuclear energy, with its attendant risks?” and “What should go into formulating a sensible answer? What, after all, is the central point?”

In looking at energy, it’s really all a question of magnitude. Ask how much. How much energy is produced? How much energy can be produced? It is energy alone that powers civilized societies—without energy there would be no civilizations. Huge amounts of energy are needed to sustain one. Do the alternatives to fossil fuels, and indeed to nuclear energy, really measure up?

So in considering nuclear power we need to think about what the alternatives really are. Nuclear power has magnitude—it can supplant fossil fuels entirely in producing electricity, and electricity can substitute for most other forms of energy. Well over a third of our energy goes to generate electricity today, and, if electricity is needed to substitute for other energy forms in the future, even more could be.

But what are the possibilities of proposed alternatives? After all, methods to take the place of fossil fuels must supply electricity in huge amounts—all the energy required, in fact, to light, heat, cool, manufacture, and generally supply power to our nation.

Fossil fuels, oil first and above all, then natural gas and coal, power the nation today. What do all these have in common? They are the producers of greenhouse gases—coal about double natural gas, oil somewhere in between. But make no mistake, all do. Natural gas is occasionally presented as environmentally benign, but its product is CO₂, just like coal and oil. If in fact global warming is occurring and is due to human activities, all three of the principal fuels that power our
nation and the world are at fault.

But, perhaps more to the point, all three are finite in amount. What is plentiful today, and reasonably priced, cannot always be. The end is most certainly only a question of when. And foreign sources will increasingly dominate, as they do now for oil, and will increasingly do for natural gas as well.

Only coal remains plentiful in the United States. However, the largest reserves underlie the west, their recovery requires extensive strip mining, and their coal is high in sulfur content. But coal today produces half the electricity in the US, while natural gas and nuclear, about equally, provide the lion’s share of the rest.

Proposed alternatives, the “renewable” energy sources, are generally solar, of which there are of two kinds. The first is solar energy collected by natural processes on earth. Sunlight evaporates water, rain deposits water at higher elevation, and hydro power is produced by turbines when the water flows again to lower elevations. Sunlight produces growth in living things; we burn the trees and we burn the methane from animal wastes. Sunlight creates the temperature gradients that cause the air to move, and wind turbines are put where the wind is strong.

Secondly, sunlight can be collected by man-made devices to give high-temperature heat to run steam turbines or, for photovoltaic devices, to produce electricity directly.

But how much energy? That is the key question.

Hydro produces substantial amounts, about seven per cent of our electricity, a third of the amount produced at present by natural gas or nuclear. Most would consider hydro renewable—rain after all is a yearly fact—but Carol Browner, the EPA Head in the Clinton administration, removed it from the list of renewable sources because dams flood the areas above them.

Without hydro, all renewable sources, both natural and man-made, produce only two percent of our electrical power. Worse, the bulk of this is from burning wood and waste, which does nothing to help with CO₂ emissions: they are hydrocarbons too.

And all high-tech collectors and wind power, added together, produce just one quarter of one percent of our electricity. It was in the late seventies that the Carter administration called for a “national commitment to solar energy” and set a goal of producing twenty percent of the nation’s energy from solar. In the twenty-five-plus years since, even with substantial tax breaks and subsidies, just one four-hundredth of our electricity is the best that could be done.

The reason is simple. Solar energy is dilute. Once it’s collected, the various applications become possible. But to collect it in the amounts required to make a real difference is hugely difficult. There is no shortcut—no technology can be invented to surmount it: massive areas of the earth’s surface would have to be devoted to it. Solar energy has been well understood for well over a century. The amount of solar energy falling on the planet is known, fixed and unchanging. If solar is to make a contribution on the scale of present energy needs, the areas required for collectors are on the scale of entire states.

Increasing efficiency to the limit the physics allows does not alter the issue. The scientific and engineering realities are plain. The amounts of materials, even cheap materials, the land areas occupied, the maintenance required, and also, more than possibly, the lawsuits brought by the very environmental industry promoting solar, make the whole solar enterprise on the scale required to power the nation a mere dream—not a practical reality now, and not in the future.

Wind power has increasingly been put forward as a realistic option. Wind turbines today generate a small fraction of one percent of our electricity. Wind turbine farms require large areas of land also, for reasons to do with the aerodynamics of the wind turbines. Nowhere does the wind blow all the time, and a utility cannot supplant any normal generating capacity with wind turbines—power so generated cannot be guaranteed to be there when it is needed. There are a variety of other engineering problems to add to a utility’s difficulty in including wind generation in its mix of sources, so that only a small fraction of a utility’s electricity can come from windmills. This will always be so. The amount of wind power the Unites States has now about equals the output of one medium sized conventional power plant, and even that is due largely to construction subsidized by generous federal tax credits.

Other non-conventional sources—geothermal, ocean waves, tides—at best can make only marginal contributions to our energy supply.
To sum up, it is not as though plentiful alternatives exist, and one can be weighed against another and a judicious selection can be made on the basis of economic, environmental, and other considerations. The alternatives to fossil fuels that could supply the bulk of the nation’s energy are very, very few—in fact, there’s only one.

To be blunt, there are the fossil fuels and there is nuclear.

Failure to recognize this, while focusing on options that do not and cannot supply the required amounts of energy, will inevitably lead to increasingly dangerous energy shortages. Who then will answer? Will the environmental activist, who blocks real options, and puts forth options that cannot meet the need?

The termination of the IFR program was their cause, although nuclear is the only realistic option to substantially replace fossil fuels. And an IFR-like technology is necessary to make nuclear fuel inexhaustible.

PART THREE: THE TERMINATION OF THE IFR

Part Three describes the events surrounding the termination of the IFR program, and Part Four lays out considerations pertaining to the choice of nuclear power technology options. Various nuclear options do exist, some more immediate, some more far-reaching than others. In the latter lies the best hope for the future.

The end of the IFR was signaled in Bill Clinton’s second State of the Union address in early 1994. Development of the reactor that consumed much of its own waste, was largely proof against major accident, and was so efficient that fuel supplies would be inexhaustible, was to be terminated immediately. The bright promise of an energy future with a new, much improved reactor system was to be extinguished.

The new Clinton Administration had brought back into power many of the best-known anti-nuclear advocates. The IFR developers at Argonne National Laboratory were well aware of the implications of this disturbing development, and they were under no illusions about what the future held for them. Ten years of development work were behind them. From tiny beginnings midway through the first Reagan Administration, success after success in the development work had allowed a broad and comprehensive program to be put in place. Every element and every detail needed for this revolutionary improvement in nuclear power was being worked on. Another two years should bring successful completion of the principal elements, the program leaders believed.

In 1994, Democrats were in the majority in both houses of Congress. Anti-nuclear advocates were also settling into key positions in the Department of Energy, the department that controlled IFR funding. Other anti-nuclear people were now in place in the office of the President’s science advisor, in policy positions elsewhere in the Administration, and in the White House itself. The IFR had survived the first year of the new Administration on its unquestioned technical merits, but only after some debate within the Administration. But the President’s words were chilling, “We will terminate unnecessary programs in advanced reactor development...”

The one-sided fight was on. The President’s budget, submitted to Congress, contained no funding for the IFR. There is no funding source to tide over a National Laboratory when funding is cut off—the program is dead and that is that. Democrat majorities in the House of Representatives were nothing new, and in themselves they were not especially alarming to the IFR people. During the previous ten years the votes on IFR funding in the House had always been close, and although a majority of the Democrats always opposed, enough of them were in support that IFR development squeaked through each year. The Senate votes on the IFR, sometimes with Republican majorities, sometimes without, as a rule went easier. But this was a very different year: the Administration had gone from weak support of the IFR program to active opposition.

Congressional staff, some of whom later moved to staff the White House itself, began coordinating the opposition to the IFR, in support of the Administration’s decision to terminate its funding. The usual Congressional hearings followed, testimony pro and con was offered, and in the end the House of Represen-
tatives upheld the President’s position. The battle moved to the Senate. There everyone knew the vote was going to be close. The key to the Senate position was Bennett Johnston, Democrat of Louisiana, and Chairman of the Energy and Water Subcommittee of the Senate Appropriations Committee. This committee oversaw IFR funding in the Senate.

After lengthy testimony, Johnston decided to fight for continued IFR development. That set the stage for a full-scale Senate floor fight. It took place over a period of several hours. The pro-IFR forces were led by Johnston himself. He had like-minded colleagues in both parties give supporting speeches, and he himself summarized the need for continued development of the IFR. Johnston had been involved in energy matters for decades, knew his subject, and matter-of-factly put the case for the IFR. He stressed the likely need in the light of the vastness of future energy needs.

The anti-IFR forces were led by John Kerry. He was the principal speaker and the floor manager of the anti forces in the Senate debate. He spoke at length, with visual aids; he had been well prepared. His arguments against the merits of the IFR were not well informed—and many were clearly wrong. But what his presentation lacked in accuracy it made up in emotion. He attacked from many angles, but principally he argued proliferation dangers from civilian nuclear power.

While all serious weapons development programs everywhere in the world have always taken place in huge laboratories, in specialized facilities, behind walls of secrecy, and there has been negligible involvement with civilian nuclear power, it is impossible to argue that there CAN be none. For this reason the IFR processes were specifically designed to further minimize such possibilities, and, if developed, they would have represented a significant advance over the present situation. This did not slow Senator Kerry, as he went through the litany of anti-nuclear assertions, articulately and confidently.

After both sides had their say the vote came, and the pro-IFR forces prevailed. But now the funding bill had to “go to conference”—a compromise committee of both houses whose job was to consolidate the different versions passed by the two houses into one bill to be sent to the President for signature into law. There was brief hope that IFR development could continue even in the face of the powerful opposition.

But the conference committee, behind the closed doors normal to such meetings, upheld the House position. There was to be no IFR funding. The IFR was dead.

A few weeks later, the mid-term elections swept Republicans into power in Congress. The IFR votes had always been politicized. With some significant exceptions, in fact just enough each year to fund the IFR, the vote had always been along party lines. Had the IFR been able to hang on for a few more weeks its development almost certainly would have gone on to completion.

Instead, it became the path not taken.

PART FOUR: ASSESSING THE FUTURE

We have traced the history of the IFR development, its benefits, and its termination before it could be perfected. Its most important aspect was the promise of unlimited fuel supplies—the promise of energy, domestically generated, unlimited in amount or time. We have seen the inadequacy of proposed alternatives to fossil fuels other than nuclear. Underlying all discussions of energy always is the shadow of war—war over adequate energy supply: whether expressed as religion, or political theory, or nationalistic aspirations, adequate energy is the driver. Adequate energy is the fuel of civilizations. History provides abundant evidence that nations will not stand idly by as their energy supplies are choked off, or even significantly threatened. Powerful nations will use their power.

Today the realities of energy supply may be influencing some of those who long have actively opposed activities to assure adequate energy at reasonable cost. It seems strange to hear of the founder of Greenpeace testifying to Congress on his new belief that nuclear power must be pursued. However, his views most vehemently are not those of the organization he founded.

Nuclear power is significant in President Bush’s energy policy, and the President has been appropriately vocal in its support.
These are important developments.

Today there may be a majority coalescing of those who see that nuclear power must be given an increased role. But just what role, it is fair to ask, and indeed nuclear power in what form? Are existing reactor types good enough? Do we just need more of them? What of advanced reactor types? Are there alternatives to present reactors? IFR development was terminated ten years ago. Have there been significant accomplishments in other directions in nuclear power in those years?

These are matters that can and must be assessed accurately. There is plenty of knowledge today to do so. Nuclear power now has sixty years of history. And this much is certain: The assessment to be acted upon today must be insightful and it must be correct. It is in the nature of things that there will be few further chances. So what should be done in the coming years?

The Light Water Reactor, the LWR, is the reactor type that must be built in the United States when new nuclear power construction begins. That’s it for the initial thrust. Nothing experimental, nothing untested. Every single one of the current hundred or so reactors in present use by U.S. utilities use is an LWR. This reactor type has proven itself over and over again. Its one accident over twenty five years ago, in TMI-2, while highly publicized, and damaging to equipment, hurt no one. Since then the reactors themselves, the operational procedures, and the crews that operate them, have all improved greatly. There have been no accidents, no even marginally serious events, over these twenty five years.

Accidents in any large system, nuclear or non-nuclear, are possible always, but the probability in these systems is very low, and becomes lower with each year of experience operating them.

As with oil refineries, also absolutely vital to the national energy infrastructure, no nuclear plants of any kind have been ordered since 1974. Environmental activists, with their lawsuits, have made construction too unpredictable and thus too financially risky.

With the current Administration this may be changing, and the situation may soon allow some progress to be made. The first reactors built when construction starts again must be reliable workhorses. LWRs fill that bill.

Are they suitable for the long term?

No. They very effectively produce electricity. However, their efficiency is limited by the relatively modest operating temperature allowed by their water cooling, and they use fuel very inefficiently; less than one percent of uranium mined is consumed in this type of reactor, the rest being “waste.” No significant improvement is possible. The principal characteristics, good and bad, are set by the materials they are made of, and they are not changeable: the present reactor therefore is not a logical candidate for further R and D.

There are two, and only two, such candidates—which, in all likelihood, will compete for precious funding. They have very different properties, and, successfully developed, they would have very different purposes. Neither is new: the possible characteristics of each have long been known. Both require R and D to make the potential characteristics real.

The one currently favored is the High Temperature Gas Cooled Reactor, the HTGR, which will operate at temperatures, it is hoped, that will be high enough to allow hydrogen to be produced by heat-related processes. The aim is laudable, because hydrogen, with development, can substitute for oil in transportation. Hydrogen is certainly no source of energy. It must be generated by a real energy source, through electrical or heat-related processes.

Either way, hydrogen generation is not particularly efficient, in that net energy is lost. Further, the energy source must be large to make enough hydrogen to meet transportation needs. Nuclear energy would be ideal, avoiding as it does further fossil fuel depletion with the accompanying greenhouse and other undesirable gases.

The weaknesses of the scheme lie in the very temperatures needed for hydrogen production, which place great strain on the materials used in the reactor plant: candidate materials, in fact, are at this point quite untested. Additionally, the HTGR does little to increase the uranium fuel utilization. Depending on specific design, it may use uranium resources somewhat more efficiently than the LWR, but that too is unclear, and it certainly is true that any improvement over the LWR in this area would not be enough to matter much overall.

This is a serious weakness, for it means that the HTGR in no way alters the need for a reactor type that can extend fuel resources indefinitely, preferably to the
point that they become inexhaustible. This, of course, was the promise of the IFR.

The main need for advanced reactor development is this: inexhaustible domestic non-fossil fuel supplies. The technology of course need not be that of the IFR. But its characteristics have to be very similar to the IFR’s, and the technical realities make it certain that it will resemble the IFR no matter what the precise technology is.

Development of the IFR was terminated before the principal element in the fuel processing could be proven—successful, full-scale separation and collection of the new fuel mixture from the spent fuel. This mixture is composed of plutonium, americium, neptunium and curium, the so-called man-made elements, as well as some residual uranium. It is a mixture most unsuitable for weapons but ideally suited to fuel reactors such as the IFR.

The process was demonstrated successfully at small, laboratory scale. But it is a very big step to scale up to practical amounts. And this is precisely where the development was aborted; the large scale equipment was largely in place, as were the skilled personnel, but the work had not yet started.

Years later, two or three inconclusive tests were tried, but did little to settle questions of practicality.

A process that accomplishes what is required must be proven at scale before any IFR type reactor system can go forward.

The hard truth is this: Only nuclear power can satisfy humanity’s long-term energy needs while preserving the environment. For large-scale, long-term nuclear energy, the supply of nuclear fuel must be inexhaustible. That means the power system must have characteristic very similar to those of the IFR.

It is those very characteristics that led the proponents of this reactor type to single it out for development, and it is also precisely what caused, and very likely will continue to cause, its opponents to single it out to be stopped.