Accelerator-Driven Transmutation Technology

The Los Alamos National Laboratory ADTT Update

No. 1, July 1994

Where Has All the N-Waste Gone?

The answer to this question is "nowhere;" and it will remain the same for a long time into the future. This question and answer typify the dilemma facing the nuclear industry—what to do with high-level radioactive waste generated by nuclear reactors during their operation.

In these environmentally-conscious times, waste generated by any industry creates an issue of how to dispose of it in a benign and acceptable fashion. Nuclear waste has certain well-known features that place it in a special category. First, it lingers, exhibiting its radioactivity for long periods of time—timescales of tens or hundreds of thousands of years. Secondly, the waste's inherent radioactivity and the general public's fear of things radioactive magnify the problem. What is the radioactive waste that is of concern? Where is it now? Why is it so long-lived, and what can be done about it?

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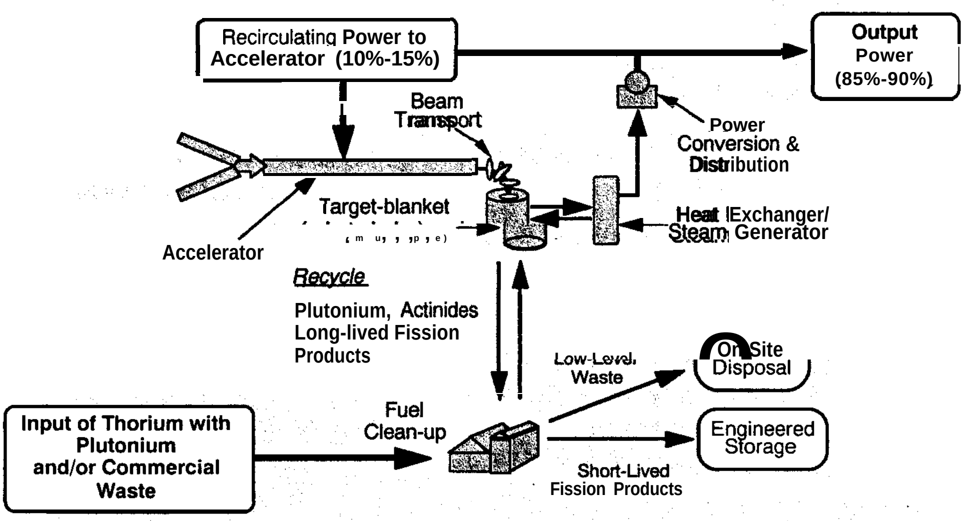
What's ADTT?

Accelerator-driven transmutation technology (ADTT) is a collection of programs that use a blanket assembly driven by a source of neutrons, neutrons that are produced when high energy protons (from an accelerator.) strike a heavy metal target. Specific assemblies can be optimized for each of the applications: production of tritium, destruction of weapons-grade plutonium, burning of spent fuel from commercial nuclear reactors, and production of electric energy.

Alphabet Soup

The four programs within ADTT which share the accelerator-driven transmutation technology are the Accelerator-Driven Energy Production or *ADEP*, the Accelerator Transmutation of Waste or *ATW*, the Accelerator-Based Conversion (of plutonium) or *ABC*, and the Accelerator Production of Tritium or *APT*.



Facility for ADEP, ATW, and ABC

Accelerator"Driven"

These processes are driven by an accelerator with a high-energy proton beam (800-1000 MeV) that smashes a target atom into many atomic fragments producing a large number of neutrons (around 20–30 per atom smashed). The neutrons can penetrate into the nuclei of neighboring atoms and be captured. This capture changes the nuclear identity of the atom capturing the neutron; thus the term *transmutation. So* the neutrons are the invisible alchemists that do the work of transmuting various elements.

Accelerator-Driven Energy Production (ADEP)

In 100-200 years or beyond, our non-renewable energy resources will run out. This finality has driven the search for a clean, renewable energy source more or less since the dawn of the industrial age. Yet fusion always seems to be twenty years away, and nuclear power continues to struggle both to re-win public acceptance and to secure viability for nuclear storage.

ADEP promises an alternate means of generating electricity ina way which can greatly extend our existing resources. It is also *intrinsically safe* in the event of complete loss of cooling, and would not produce a waste stream that requires management for thousands of years. It begins with the accelerator-generated source of neutrons surrounded by an assembl y (that looks like a reactor) consisting of a graphite moderator and a fuel that produces energy through fission. The fuel is embodied in the coolant—a lithium-beryllium fluoride molten salt to facilitate a high-temperature, high-efficiency operation with easy fuel management. The net power produced is many times that needed to drive the accelerator.

The system differs significantly from today's reactor. First of all, the assembly is subcritical and cannot sustain a chain reaction without the accelerator beam (switch "off' the beam and the power drops instantly). Secondly, the fuel is thorium which is almost an unlimited energy source. The energy comes from the fission of ^{233}U which is derived from neutron absorption in ^{232}Th. The system generates very little higher actinide waste such as ^{239}Pu and can destroy its own fission products. This leads us to the ATW concept.

AcceleratorTransmutation of Waste (ATW)

The capacity to burn waste comes from the enhanced neutron economy made possible by the presence of the extra accelerator-produced neutrons, The better neutron economy increases the capacity to burn (transmute) anything that absorbs neutrons, including long-lived fission products and actinides. By deliberately paying attention to these wastes and burning them in the accelerator-driven assembly, the results can be quite spectacular.

Typical commercial reactor spent fuel contains embedded actinides and fission products, some of which are radioactive for hundreds of thousands of years. Since the integrit y of man-made structures cannot be assured for such along time, it is planned to store these materials underground where geologic features can be employed to confine the wastes. Although much work has begun on such a solution, there is still a great deal of concern about the ability to confidently predict confinement performance for such an enormous time span.

In an accelerator-driven system, the resulting waste problem is much different because the waste has been transmuted or "burned" in the system. The mass of long-lived radionuclides in disposed radioactive waste can be reduced by factors approaching 1000. The storage times of residual products could be greatly reduced from hundreds of thousands of years to several centuries. This considerable waste stream reduction in both mass and half-life clearly brings commercial and nuclear waste storage and secure disposal into a regime of greatly increased confidence.

Plutonium Burning—Accelerator-Based Conversion (ABC)

In the ABC design, the fuel can be either weapons-grade plutonium or commercial reactor spent fuel containing plutonium. For the case of weapons-plutonium feed, the performance of the ABC is such that in a single cycle, 98% of the ^{239}Pu and 90% of all plutonium isotopes are burned. A reactor in its cycle can achieve about 90% burn-up of ^{239}Pu and 70% of the plutonium isotopes. Expressed differently, the ^{239}Pu and total plutonium in a single cycle in an accelerator-based system are reduced by factors of 50 and 10 respectively, whereas for reactors, these numbers are 10 and 3. By following the plutonium burning with highly enriched ^{235}U, all plutonium can be completely destroyed.

AcceleratorProduction of Tritium (APT)

Because tritium decays at a rate of 5.5% per year, it is the only nuclear material that must be produced to maintain the nation's strategic deterrent. In the past, tritium has been produced in nuclear reactors that, as a by-product, have left a legacy of high-level waste from the fissioning of uranium. Those reactors are now effectively retired. Anew tritium production facility must come on-line sometime between years 2008 and 2012 to produce the quantity requested by the DOE. The Accelerator Production of Tritium (APT) project is part of a national effort consisting of Los Alamos, Brookhaven and Sandia National Laboratories and several industrial partners, to design an accelerator system that is an environmentally attractive alternative to the nuclear reactor.

In the APT system, spallation neutrons generated by a 200-mA beam of protons from a 1000-MeV linear accelerator strike an assembly called a target/blanket. The target/blanket is the subsystem that produces tritium. In the target/blanket, neutrons produced by proton spallation of a heavy-metal target are moderated in either heavy or light water, depending on the design, and captured in a material that produces tritium through neutron absorption.

The Los Alamos design uses a tungsten-lead composite target, a heavy-water moderator, and an isotope of helium, 3He, contained in aluminum or inconel structures in order to make tritium. Because both tritium and 3He are gases, the tritium can be continuously extracted and purified onsite using well-tested processes. The design being developed at Brookhaven uses heavy-water-cooled lead to produce neutrons, and a surrounding light-water moderator containing enriched ^{6}Li alloyed with aluminum. The tritium is extracted by melting the LiAl in a furnace and passing the released tritium into a facility similar to that used in the Los Alamos design for purification.

In contrast to reactors, an APT system can produce the required tritium without the use of any fissile material; thus, criticality is not an issue and there is no resultant high-level waste. Also, the accelerator can shut down almost instantaneously (a unique safety advantage), virtually eliminating the possibility of a serious accident. Redundant target systems are also under consideration in each design to offer extra plant reliability y. In addition to safe, reliable operation with clear siting and environmental advantages, an APT system (the present design) would have a lower capital cost and a more rapid construction schedule. With the present policy to keep tritium production for weapons separate from commercial power production, the life-cycle costs of an APT system should be substantially less.

The Promise of ADTT

Accelerator-driven transmutation technology, with its external source of neutrons, provides all the above opportunities. It offers significant safeguards and non-proliferation advantages. Its programs include the production of tritium without fission reactors and their associated waste streams, the burning of weapons plutonium until it is "gone forever," the potential to burn commercial reactor spent fuel down to levels that do not require radioactive storage for hundreds of thousands of years, and finally, the opportunity for producing energy from the abundant element thorium in a safe, subcritical assembly with minimal and manageable long-term waste. *What program could offer more?*

N-Waste

(Continued from Page 1)

The type of nuclear waste that we are discussing here is classified as "high level." In the United States, such high-level radioactive waste must be disposed of according to strict EPA requirements that call for its isolation from the accessible environment for periods on the order of ten thousand years (more than the timescale of recorded history). Since no repository facilities capable of isolating such waste over these timescales have yet been approved anywhere in the world, high-level radioactive waste continues to accumulate at reactor sites. Presently, spent reactor-fuel elements are stored in swimming-pool-type facilities. In the US, facilities for such on-site storage are dwindling—an issue of significant concern for utilities who may wind up having no room for future fuel-element storage. This situation has led to pressure upon the government (specifically the DOE) to assume responsibility for spent fuel starting in 1998. In the meantime, this date has slipped, leading to the possibility of legal action by utilities and their rate payers against the government. This situation has prompted utilities to investigate other interim means such as monitored-retrievable storage (MRS) facilities. One proposal attracting considerable attention is that of the Mescalero Apache Indians for a facility that would be built on tribal-owned lands.

Long-Lived Waste Constituent	Fraction Remaining (%) after 500 yrs.	1000 yrs.	10,000 yrs.	100,000 yrs.
Technetium -99	100	100	97	72
Iodine -129	100	100	100	100
Plutonium (All)	88	85	58	8
Neptunium -237	100	100	100	97

Relative Quantities by Mass of Long-lived Isotopes Occuring in Spent Reactor Fuel.

(ADTT Systems will eliminate 100% of all these materials during the operational life of the systems: -30 years)

Long-Time Contributors to Nuclear Waste

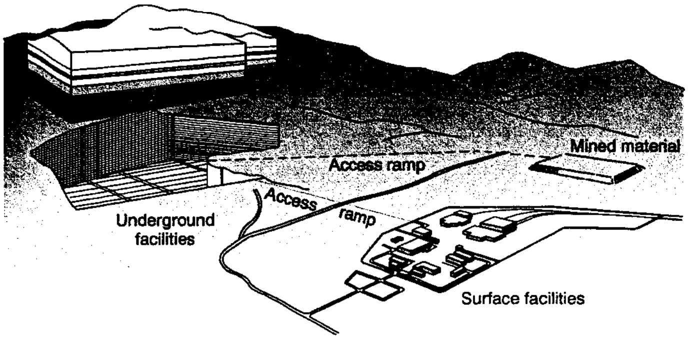
Why are the wastes so long-lived? High-level nuclear waste consists of two main sets of materials: (1) the actinide heavy elements, most notably plutonium (half-life of 24,000 years for ^{239}Pu) plus other substances such as neptunium (half-life of 2,000,000 years for ^{237}Np) and americium; and (2) the lighter elements created when the actinides fission. Although greater than 95% of such fission products are nonradioactive or have short "half lives'' for decay of less than 30 years, there remains a relatively small number that are long-lived species such as ^{99}Tc, ^{129}I, ^{135}Cs. The table illustrates how slowly these materials decay. The presence of these materials in high-level radioactive waste creates the need for long-term isolation from the biosphere.

Both types of long-lived waste products present separate challenges to repository designers worldwide. The long-lived actinides contribute principally to radiotoxicity associated with high-level nuclear waste. As long as they stay in the repository, this is not a problem; however, events such as earthquakes, volcanoes, and accidental (as well as deliberate) intrusion could release these materials.

Long-1 ivedfission products such as ^{99}Tc contribute to a different type of risk associated with repository storage. Because these materials are more chemically mobile than actinides, they have a greater chance of reaching the biosphere in the future. They represent the major contributor to the long-term risk associated with a repository (as pictured at top of page 5).

Possible Solutions

What can be done with accumulating inventories of high-level nuclear waste? The solution pursued as the mainline effort by the major nuclear countries in the world is repository disposal. While accepted uniformly by the scientific community, public opposition has delayed opening of any repository in the world. For example, twenty years ago when



Repository Storage Concept Proposed for the Yucca Mountain Site

Yucca Mountain was first proposed, the projected opening time was six years after project initiation. Now, this time estimate is more than 20 years. Another issue is the number of repositories needed worldwide to handle nuclear waste. If the present amount of nuclear-generated electricity stays constant at its present level (325 gigawatts), then a major repository would be required to open somewhere in the world every ten years or so. Nuclear electricity generation is projected to grow significantly (perhaps as much as a factor of ten according to conservative estimates from the Electric Power Research Institute) in the next fifty years. This increase implies that a large repository would be required somewhere in the world every 1–2 years.

Are there alternatives to present-day repository scenarios? Partitioning and transmutation technologies exemplified by the Accelerator Transmutation of Waste (ATW) concept can provide enhancements and alternatives. A partitioning and transmutation approach involves removal of the long-lived radionuclides followed by their transmutation (through the use of nuclear reactions) to stable or short-lived by-products. This approach attacks the long-lived waste problem at its heart.

To do this, the ATW concept provides attractive transmutation features not available in other approaches. The first of these features is **completeness;** specifically, it can destroy all major types of long-lived radionuclides, both fission product and actinide species described earlier. Reactors cannot simultaneously achieve these goals because of limitations in their "neutron economy." Simply speaking, reactors must generally use all the neutrons produced during fission to sustain the nuclear chain reaction associated with critical operation. The accelerator system of ATW injects a second source of neutrons which can transmute troublesome fission products while simultaneously destroying actinides. In doing so, ATW significantly reduces or eliminates altogether the risks associated with long-term disposal.

The specific choice of design of the ATW concept—use of fluid fuel carriers—allows creation of high-neutron flux systems which operate in energy regions where nuclear cross sections are large. This leads to the second attractive feature of ATW, the smaller inventories of radioactive materials needed in the system to sustain a desired transmutation rate. **This low-inventory feature,** in turn, has a significant overall system impact in that the times required to significantly reduce long-lived radioactive materials to very low levels are much less than that for other nuclear concepts.

Finally, the third attractive feature of ATW is that the accelerator allows **subcritical operation,** where the neutron-propagated chain reaction stops when the accelerator beam is turned off. This adds an important new element of control and safety into ATW'S nuclear system.

Successful operation of ATW systems will have significant impact on the long-lived radioactive waste problem. By destroying certain key long-lived radionuclides, risk sources could be reduced by factors of 1000 or more. The remaining waste stream could be handled mainly in engineered storage facilities. Other material coming out of ATW and from the spent reactor fuel such as uranium and zirconium could be held for future use.

Returning to the question: *Where has all the N-waste gone?,* ATW technology can provide an approach which significantly reduces risks to future generations from nuclear waste generated by today's society. In its ultimate form, it could lead to a tractable solution to the high-level nuclear waste problem involving facilities and timescales within the grasp of human experience and knowledge.

LAMPF ADTT Experiment

While there has been much talk over the years about the successful merger of accelerator and reactor-like technology, a successful demonstration of this at a significant scale has yet to be achieved. LAMPF is the most powerful accelerator in the world in its energy range. With its 800-MeV proton beam and current of 1 mA (0.8 MWt in the beam), it is capable of driving a subcritical system to substantial power levels (for instance, a system with a multiplication of 10, $k_{eff} = 0.90$, could obtain a power level of 20 MWt under full beam). Steve Wender is the Project Leader in the ADTT office for the design, construction, and operation of an experiment at LAMPF to demonstrate the first successful merging of accelerator and subcritical blanket technology. The experiment would incorporate a liquid-lead target which will be surrounded by a tank containing a graphite moderator with molten salt flowing through holes in the graphite. The tank will be about 3.5 meters in diameter and about 3 meters high. Heat is removed from submerged heat exchangers which transfer the heat from the primary salt to a secondary salt loop. In order to simplify ES&H issues, no on-line separations will be incorporated into the experiment. Access for sampling and other functions will be provided. This experiment will demonstrate many essential features of an accelerator-driven transmutation system, some of which will include an integrated demonstration of

- a liquid-lead target
- tank-style subcritical blanket
- submerged heat exchangers
- internal pumps with external drive
- on-line criticality measurement
- integrated accelerator-target/blanket control

and verification of

- predicted neutronic performance
- calculated temperature coefficients
- expected sparging effectiveness
- predicted fission-product deposition.

The demonstration of the structural materials compatibility with molten salt is not required since this was accomplished in the Oak Ridge Molten Salt Reactor Experiment. Operation would begin with no fissile material, then would be proved at a low multiplication factor (2, equivalent to a k_{eff} value of about 0.5), and then would progress to higher power levels with larger multiplication factors as performance is demonstrated to conform with predictions at each stage of increase in k_{eff}. The experiment would have relevance to all of the various elements of the ADTT program, and could be ready for beam in late 1996 with adequate funding. It would run for about five years.

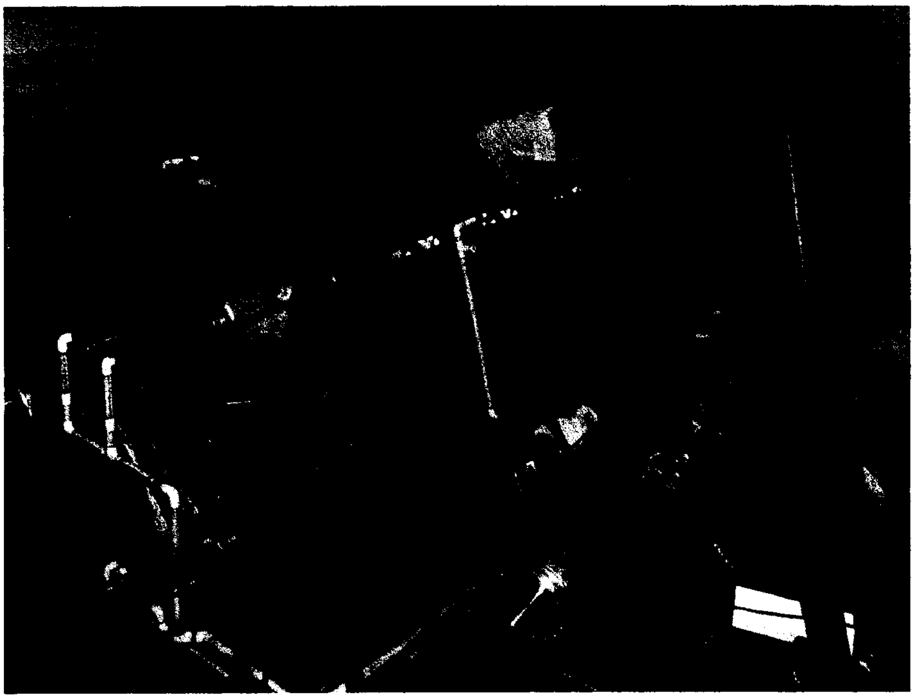
The proposed experiment by Rubbia (see article on page 8) will add an accelerator to an existing reactor-like facility, while the LAMPF ADTT experiment will add a reactor-like facility to an existing operational accelerator. The two demonstration systems might come on-line at about the same time, starting from different base facilities.

Recently Obtained Nuclear Data for ADTT

Several types of nuclear data are required for design and performance prediction of the ADTT systems. Two very successful measurements were recently completed which greatly increase our confidence in our design approach. The first involved measurement of the neutron yield per proton from a full-scale target. Our predictions of this number for lead were about 40–50% higher than earlier estimates, and we were criticized for claiming such performance. A team from the Laboratory's underground nuclear test program, under the leadership of Tom Stratton, undertook an experiment called *Sunnyside* (drawn from the approved list names for underground tests). The experiment consisted of a more-than-stopping-length target surrounded by a tank of water for moderating these neutrons. The water contained dissolved manganese sulfate; the manganese absorbed the neutrons moderated by the water, and the manganese activation was measured in a detector through which the water was circulated. The assembly shown in the photograph is about

3.0 meters in diameter and about 2.5 meters long and weighs about 30 tons. The measurement results for several different targets are given in the table where the calculated and measured results are compared. The excellent agreement provided the needed confirmation in the reliability of our calculations.

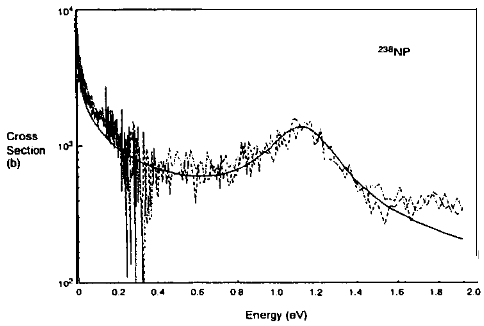
The second was a fission cross-section measurement program led by Mike Moore. Several nuclei with half lives of about *one day* must be taken into account to accurately estimate the performance of the ADTT systems. These include ^{232}Pa, ^{234}Pa, ^{238}Np and ^{242}Am (ground state). The experiment required the irradiation of the sample at the Laboratory's Ion Beam Facility, the transport of the irradiated sample to the Laboratory's radiochemistry facilities, the separation of the desired species from the target material, the deposition of the material on the fission chamber foil, the assembly of the fission chamber, the transport of the fission chamber to the LANSCE (Los Alamos Neutron Scattering Center) facility, and the collection of time-of-flight data—all *of this before the material decayed away.* The team completed measurements on ^{232}Pa and ^{238}Np, and the results for the latter are shown in the graph. The fission cross section is shown as a function of energy for a sample of three nanograms of ^{238}Np. The resonance discovered in ^{238}Np 1.1 eV will be vital for correct predictions of the burn-up rates of ^{237}Np and for the prediction of the reactivity temperature coefficient sign and magnitude.



This photograph shows **the experimental** apparatus used at **WNR** (the Weapons Neutron **Research facility of LAMPF) for a** neutron/proton yield experiment in lead, lithium, and salt. **The technician is** standing inside a three-segment tank (the third segment **is on the** floor). **The accelerator beam enters on** the left and terminates in a cylindrical pipe containing the various target assemblies. The pipe is removed from its normal position and is visible in the **lower right** portion of the photograph.

Run#/Target	Neutrons/Protons (Calculated)	Neutron/Protons (Measured)	Ratio (Meas./Calc.)
204/Lead (600 MeV)	22.2	22.2* 1.1	1.00
217/Lead (800 MeV)	22.2	22.5* 1.1	1.01
226/Lead (800 MeV)	22.2	21.6* 1.1	0.97
253/Lithium (400 MeV)	4.4	4.4*0,3	0.99
425/Lithium (400 MeV)	4.4	4.4*0.3	1.00
647/Salt (800 MeV)	12.6	11.1±0.6	0.ss

Table Showing Comparison of Experiments and **Calculations of n/p Yield (preliminary** results)



^{238}Np Fission Cross Section from Thermal to 2 **eV**

News About Tritium

The Accelerator Production of Tritium Project (APT) has a new leader. Paul Lisowski was named Project Leader after former APT leader, John Ireland, accepted a new position as Deputy Director for the Technology and Safety Assessment (TSA) Division. John did a great job in bringing us this far, and we are pleased to have Paul take over. Paul was one of John's associates in the APT program and the one who originated the Los Alamos technical approach. Paul has been Group Leader of the Neutron and Nuclear Science Group in the Physics Division and will continue to carry that responsibility along with his new position as APT Leader.

APT Project leader Paul Lisowski

The Los Alamos APT program is part of the DOE's accelerator production of tritium program which includes a different accelerator-driven concept being developed at Brookhaven National Laboratory, both of which compete with reactor systems for tritium production. All of these systems are scaled to produce 3/8 of the amount of tritium required to maintain the US weapons stockpile which existed before the onset of the US–FSU (former Soviet Union) stockpile reduction plans. The DOE is planning a "Record of Decision" in early 1995 to select one approach from the spectrum of accelerator and reactor options. The technology selected would then receive further support for development into the Nation's tritium source. The APT system has the advantage of no fissile material and no fission-fuel waste stream. It appears that the accelerator-driven systems become more competitive with reactors as the amount of tritium required decreases. We believe that the Los Alamos APT system will be a serious competitor in this selection process.

Rubbia's Program in the News

Dr. Carlo Rubbia, Nobel Prize winner and formerly Director-General of the CERN Laboratory, has taken on the challenge of developing an accelerator-driven system for nuclear energy production based on the therium-uranium cycle. His plans have received much attention in the European public media and are a common subject of discussion in the European scientific community. Undoubtedly, his entry into this field will be beneficial to the overall ADTT program, particularly for the energy production part which has been harder to advance in the US than the other elements of our program. Rubbia's approach is somewhat different from ours in that he plans to use solid fuel and has no plans for actinide or fission product transmutation. He believes that the very substantial benefit of virtual elimination of plutonium production using the Th-U cycle and the subcriticality features are sufficient to justify the development and deployment of this new technology. The systems would be smaller power units driven by a sector-focused cyclotron of about 10 mA at 1 GeV so that the thermal fission power would be about 500 MWt with electric power production of about 150 MWe.

After an inexpensive demonstration experiment at CERN, Rubbia plans to build a cyclotron at the Cirene reactor in Italy which was completed but never brought into operation. The core of the existing reactor would be removed and replaced with an accelerator-driven core. The accelerator cost is estimated by Rubbia to be about $100 million.

Many US scientists had their first chance to hear about Rubbia's plans at the International Conference on Nuclear Data for Science and Technology in Gatlinburg, Tennessee, held from May 9-13, 1994. Rubbia presented his concept there; his presentation was followed by Bowman's presentation on the ADTT program elements and technology direction. Apparently both talks were well received, and a story on the presentations was carried by the Associated Press.

The Las Vegas Connection

International Conference on Accelerator-Driven Transmutation Technologies Planned for Las Vegas, Nevada, Starting July 25.

An international conference on Accelerator-Driven Transmutation Technologies will take place at the MGM Grand Hotel in Las Vegas, Nevada starting July 25 and continuing through July 29. The conference will focus on system concepts built around use of an accelerator-driven neutron source. Applications include global plutonium management, transmutation of long-lived radionuclides in high-level nuclear waste, energy production, and materials research. Technology and issue areas dealing with accelerators, targets, subcritical blankets, materials, and separations will also be covered.

Approximately 200 representatives from international efforts that are examining ADTT systems and applications are expected at the conference. This includes efforts underway at national laboratories such as Los Alamos, Oak Ridge, and Brookhaven, as well as foreign efforts such as those reported recently by the Nobel prizewinner, Carlo Rubbia. In addition, efforts from Russia, Japan, France, and Sweden are scheduled to be represented.

The conference will provide a unique environment to learn about the status of accelerator-based concepts, their potential impacts on a number of application areas, and the technology inherent to them. The conference will also provide the opportunity for the national and international communities to jointly define and pursue advanced technological approaches to major problem areas.

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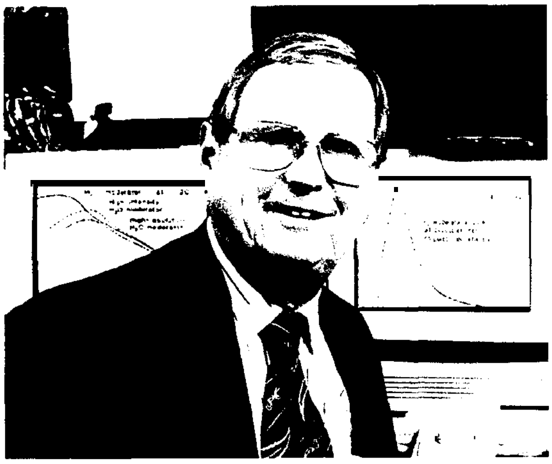
Leader's Letter

The ADTT Office knows from the enormous number of inquiries we receive that there is already a large and growing interest in the role of accelerator-driven transmutation in dealing with environmental clean-up and in the ADTT role in making nuclear energy a safe and environmentally acceptable major source of energy supply for the world. I trust that this newsletter, the first of a quarterly series, will help keep you abreast of what is happening at Los Alamos in this program.



ADTT Project leader Charles B wm

Many of you may know that the search of parameter space for the best ADTT system has been a continuous effort from the beginning of this program. Over the past several months, we have moved our focus from an aqueous to a molten salt system. This necessary change has caused some confusion, but the message of why we changed and the resulting benefits are beginning to be understood and appreciated, although communicating this message to several prestigious review committees (the JASONS and two groups from the National Academy of Sciences) has been a challenge. The highly dynamic development of ADTT contrasts sharply with the incremental progress being made in the competing reactor technology. The most important focus for the next few months is to move beyond "transparency presentations" and to publicize our message in written form suitable for the public and for scientific and engineering journals.

The ADTT project is a major effort and can best be done with an appropriate integration of effort from industry, other national laboratories, universities, and foreign countries. Los Alamos is presently working with Oak Ridge, Brookhaven, and Sandia National Laboratories, and with the active industrial partners Grumman, Bechtel, Westinghouse, Babcock &Wilcox, and Kaman in the development of this technology. The ADTT Office looks forward to optimal integration of such resource organizations into the Los Alamos program.

Please don't hesitate to contact us. Our goal is to respond in a meaningful way to each comment or inquiry.

Charles

July 1994 LALP-94-59

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Steve Wender	Experimental Program

The ADTT Update Edited by Dan Rusthoi

ADTT Calendar

July 25-29,1994	Int'l Conference on ADTT and Applications - Las Vegas, NM
Sept. 5-8, 1994	Conference on Plutonium Disposition - Dimitrograd, Russia
Nov. 10-12,1994	Int'l Conference on Global Energy Demand in Transition - Washington, DC
Jan. 8-12, 1995	Conference on ADTT and Applications - Albuquerque, NM
Sept. 3-9, 1995	5th Int'l Conference on Radioactive Waste Management and Environmental Remediation - Berlin, Germany
Sept. 11-14,1995	Global '95- Paris, France