AIIM

Association for Information and Image Management

1100 Wayne Avenu , Suite 1100
Silver Spring, Maryland 20910

301/587-8202

Centimeter

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 mm

1 2 3 4 5

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

Conf-9404184--1

LA-UR- 94-1429

~~LA-CP~~

Title: AN OVERVIEW OF ACCELERATOR-DRIVEN TRANSMUTATION TECHNOLOGY

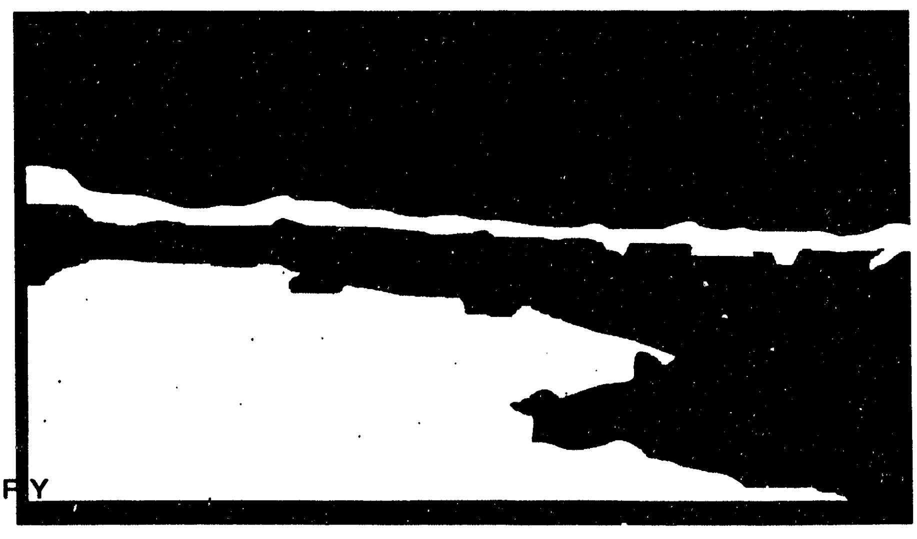
Author(s): Edward A. Heighway

Submitted to:

For the LAMPF User's Group Workshop
Washington, DC
April 20, 1994

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED



Los Alamos
NATIONAL LABORATORY

Form No. 836 R5

An Overview of Accelerator-Driven Transmutation Technology

A White Paper Prepared for the LAMPF User's Group Workshop
Washington, D.C., April 20, 1994
by
Edward A. Heighway*

Introduction

Accelerator-Driven Transmutation Technology, or ADT^2, is a collection of programs that share a common theme - they each have at their heart an intense source of neutrons generated by a high-energy proton beam striking a heavy metal target. The beam energy, typically 1000 MeV, is enough for a single proton to smash a target atom into atomic fragments. This so-called spallation process generates large numbers of neutrons (around 20 to 30 per proton) amid the atomic debris. These neutrons are of high value because they can be used to transmute neighboring atoms by neutron capture.

Three distinct ADT^2 program elements will be described. These are ADEP - accelerator-driven energy production, ABC - accelerator based conversion (of plutonium) and ATW - accelerator transmutation of waste.

Accelerator-Driven Energy Production

In 100 years or arguably more, our non-renewable resources will run out. This finality has driven a search for a clean, renewable energy source, more or less since the dawn of the industrial age.

Accelerator-Driven Energy Production (ADEP) promises a means of generating nuclear electricity in a way that can greatly extend our existing resources. It is also intrinsically safe (no run-away or melt-down) and produces a minimal waste stream not requiring management for thousands of years. This promise, which has been on the table in some form for 50 years or so, has been made practicable through advances in technology over the last decade.

The top-level system concept is shown in Fig. 1. An accelerator delivers an intense proton beam to strike a heavy metal target at the center of a surrounding blanket assembly. This assembly contains material that ultimately fissions to produce nuclear energy. Although electrical power is required to produce the proton beam, the power produced by this assembly is many times that needed for the accelerator system and so the system is an efficient net producer of energy.

---

* Written on behalf of the ADTT technology team at Los Alamos

The ADEP accelerator concept is shown in Fig. 2 and is largely a high-intensity version of the Los Alamos Meson Physics Facility (LAMPF) accelerator. In one concept an accelerator delivering 15 mA of protons at 1000 MeV (15 MW of beam power) can drive a blanket assembly to produce 200 MW of electrical power at about 40% efficiency. (A circular accelerator is an attractive option at this power level). Another configuration is to use a single, higher-current LAMPF-like accelerator to drive a small cluster of separate assemblies capable of producing a total of say 1200 MW electrical.

Fig. 3 shows the target/blanket conceptual layout. The ADEP target and source of spallation neutrons is liquid lead. This target is surrounded by the blanket assembly that consists of a graphite moderator through which flows a lithium-beryllium-thorium molten fluoride salt. The thorium is the fuel component. The thorium has been chosen for three reasons. (i) It occurs naturally as the element Th-232, which is many times more abundant than uranium. (ii) It is readily transmuted by neutrons to the easily fissionable and high fission-neutron yielding U-233. (iii) The actinide waste (such as Pu, Np and Am) produced in a thorium system is ten times or more smaller than that for uranium or plutonium systems. The possible attractiveness of the U-233 as a proliferant is negated by inclusion of a small amount of natural uranium in the thorium. This ensures that no weapons grade material can be obtained without isotopic separation.

Because thorium is non-fissile, there is a start up period in the ADEP system when no net power can be produced until enough fissile U-233 is available. This start-up dead-time can be removed by addition of a small amount of seed fissile material to the molten salt. One option for the seed material is a small amount of weapons plutonium. This has the dual advantage of increasing the effectiveness of the thorium system by speeding startup and also provides a high-value burn path for weapons plutonium.

The molten salt is chosen over an aqueous fluid medium because it allows high temperature and therefore high thermal-efficiency while also operating at low pressure. We note that the salt is of low chemical activity even at high temperature. The assembly is also totally enclosed and any shut down is inherently passively safe, even under complete loss of coolant or power scenarios. The fluid-fuel facilitates removal of gaseous and noble-metal fission products generated during operation. This improves the neutron performance of the thorium cycle. It is noted also that the surplus neutrons supplied by the accelerator greatly relax the need for removal of fission products from the salt.

The target/blanket assembly is deliberately designed to be sub-critical. As soon as the accelerator is switched off the system shuts down and does so without any special external intervention. Because the assembly uses fissile material, it does produce radioactive waste. However the accelerator-driven system has significant advantages in that it has the capacity to burn the principal long-lived components of that waste using the extra neutrons supplied by the accelerator. This is a fundamental difference between the accelerator-driven concepts and stand alone reactors, in that no reactor can breed its own fuel and concurrently destroy the waste.

Accelerator Based Conversion of Plutonium

In the design for accelerator based conversion of plutonium, the accelerator and target/blanket assemblies are very similar to those for an energy production system. The fundamental difference is that instead of thorium, the molten-salt is seeded by either weapons plutonium or commercial spent fuel containing plutonium. Again the accelerator based system enables high fuel burnup. For the plutonium converter, the performance is such that in a single cycle (no stopping because of fission product build up) 98% of the Pu-239 and 90% of all plutonium isotopes is burned. This can be expressed differently. Namely, in a single cycle, the Pu-239 is reduced by a factor of 50 and the total plutonium by a factor of 10. In contrast, reactor performance in a single cycle falls far short of these reduction factors. Thus the accelerator based system has the ability to burn the weapons plutonium completely and destroy it forever.

Accelerator Transmutation of Waste

The increased burnup capability can be applied not only to the fuel but to anything that absorbs the neutrons. So the neutrons can equally well be applied to burning long-lived fission products and actinides in spent fuel from other reactor systems. By deliberately paying attention to these wastes and burning them in the accelerator-driven target/blanket assembly, the results can be quite spectacular.

Typical reactor spent fuel contains embedded actinides and fission products that remain radioactive for hundreds of thousands of years. These wastes must be deposited in deep geologic repositories capable of denying radioactive migration to the surface for millennia. The accelerator-driven system provides a possible alternative to such geologic disposition. The extra neutrons allow the waste to be burned along with the fuel. The resulting waste stream is then much different. The mass of high-level radioactive material that has to be stored is now reduced by a factor of 100 or more. In addition, the radioactive half-life of this smaller mass is very greatly shortened and is dominated by nuclides with half-lives of about 30 years. Such a considerable reduction in both mass and half-life of the waste stream clearly brings storage and secure disposal into a regime of much increased confidence.

Summary

Accelerator-driven transmutation technology, with its external source of neutrons, provides several exciting opportunities. These include burning of weapons plutonium until it is "gone forever"; burning commercial spent fuel including fission products down to manageable levels that do not require radioactive storage for millennia; and providing the opportunity for producing energy from the abundant element thorium in a safe, sub-critical assembly with minimal and manageable nuclear waste stream.

For additional information on this technology please contact the author at

Program Office for
Accelerator-Driven Transmutation Technology
MS H854
Los Alamos National Laboratory
Los Alamos, New Mexico, 87545

Phone	505 667-1543
Fax	505 665-6927
E-mail	eah@lanl.gov

Figure 1. Top-Level Accelerator Driven Concept

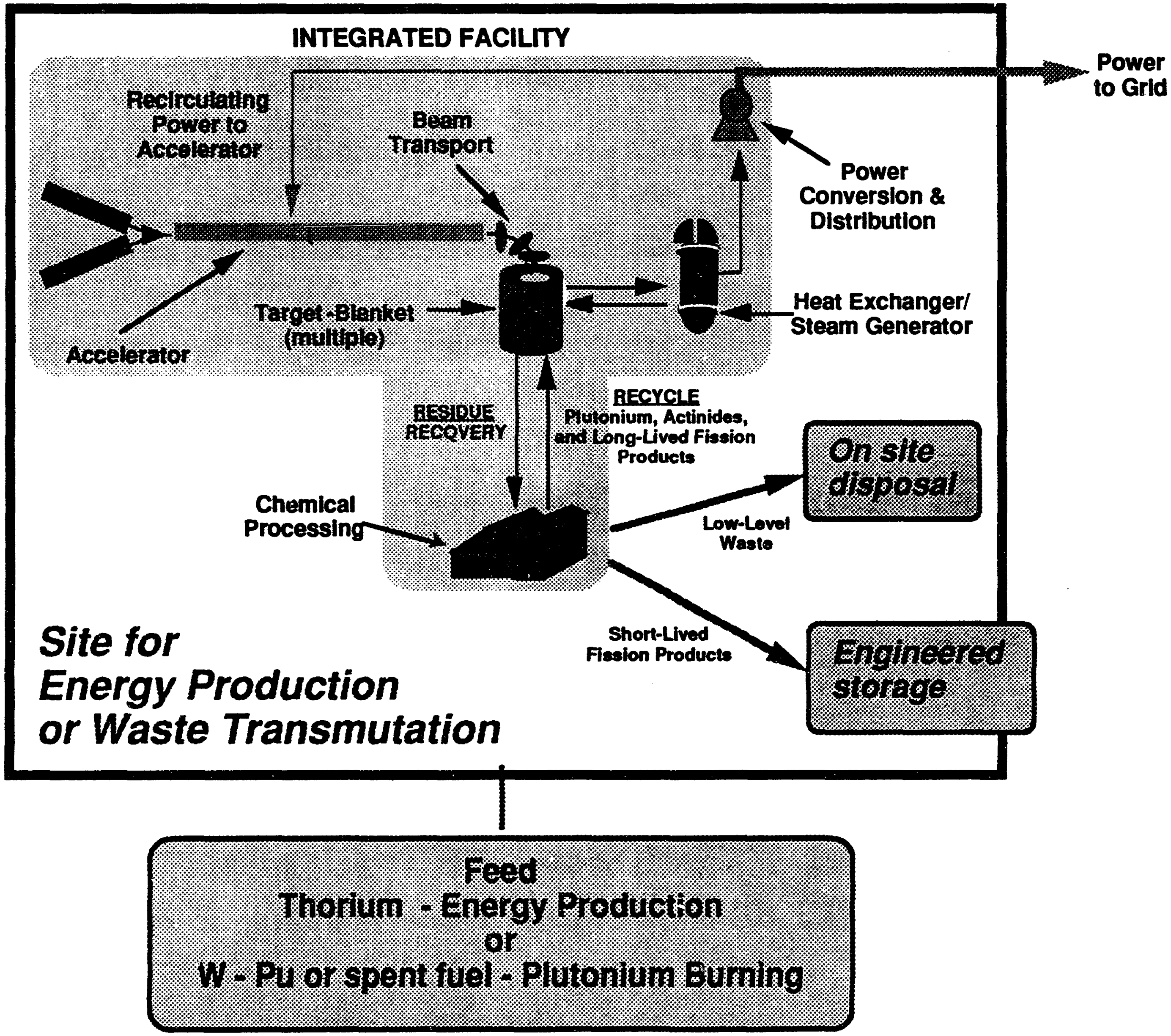
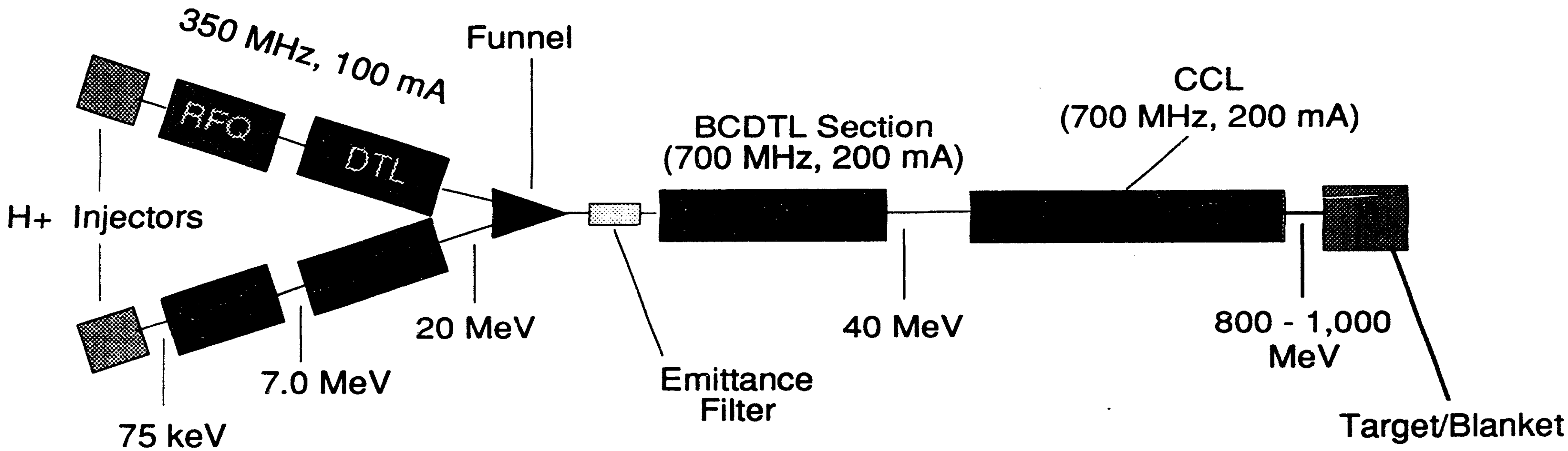


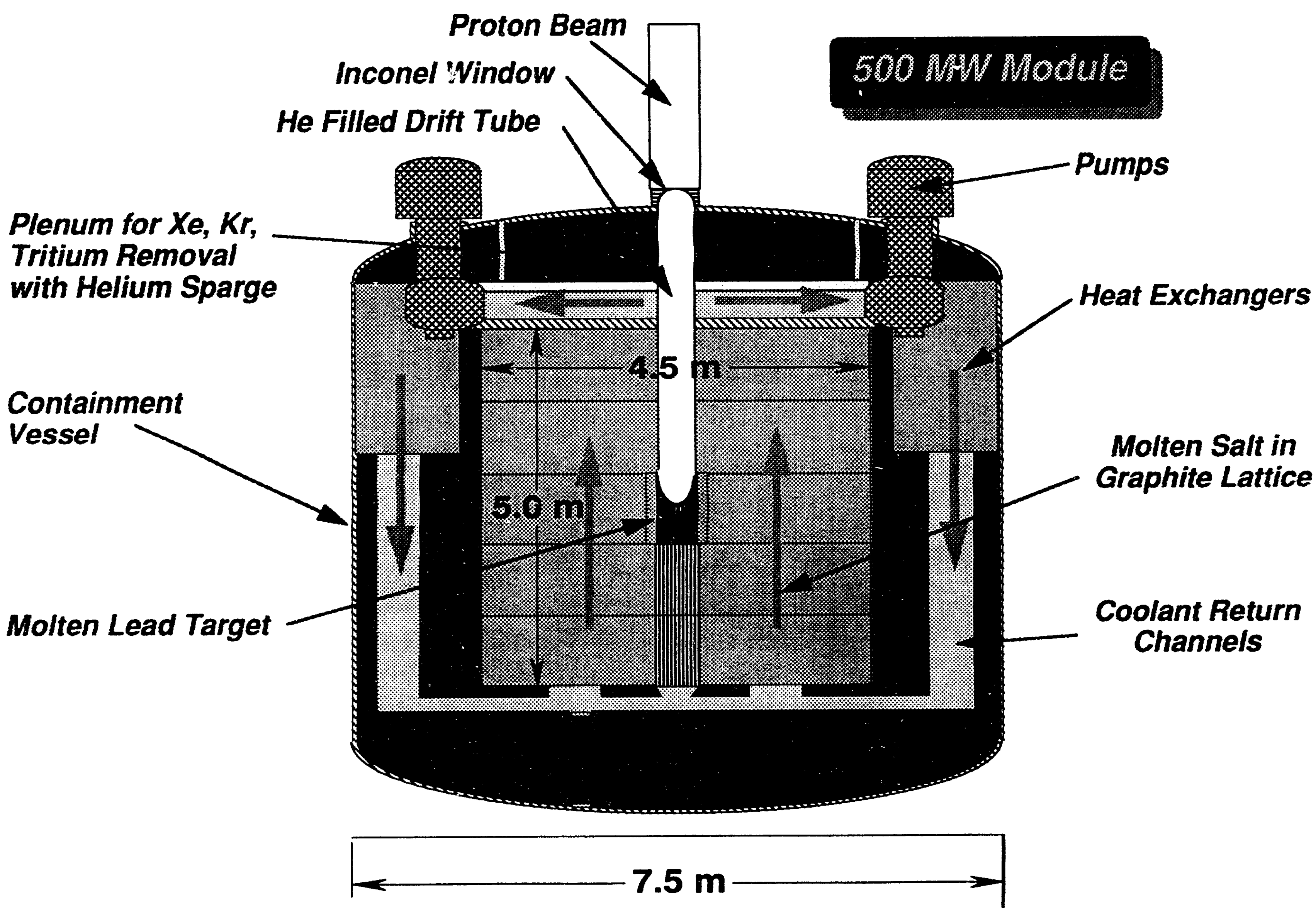
Figure 2. The Conceptual Accelerator Drive System



Component Technology

RFQ: Radiofrequency Quadrupole Accelerator
DTL: Drift Tube Linear Accelerator
BCDTL: Bridge-coupled Drift Tube Linear Accelerator
CCL: Coupled Cavity Linear Accelerator

Figure 3. Conceptual Target/ Blanket Assembly



Doc I

DATE FILMED

8/18/94

END