ROADMAP for ATW DEVELOPMENT
- Target and Blanket System -

F. Venneri, LANL
D. Crawford, ANL

Nuclear Design and Safety

H. Khalil	ANL
M. Carelli	Westinghouse

Coolant Chemistry and Materials Compatibility

N. Li	LANL
T. Allen	ANL
M. Louthan	WSRC

Heat Removal and Ancillary Systems

K. Woloshun	LANL
A. Brunsvold	ANL
C. Ehrman	Consultant
D. Wade	ANL

Target Technology

M. Cappiello	LANL
M. Louthan	WSRC
M. Chadwick	LANL
P. Lisowski	LANL

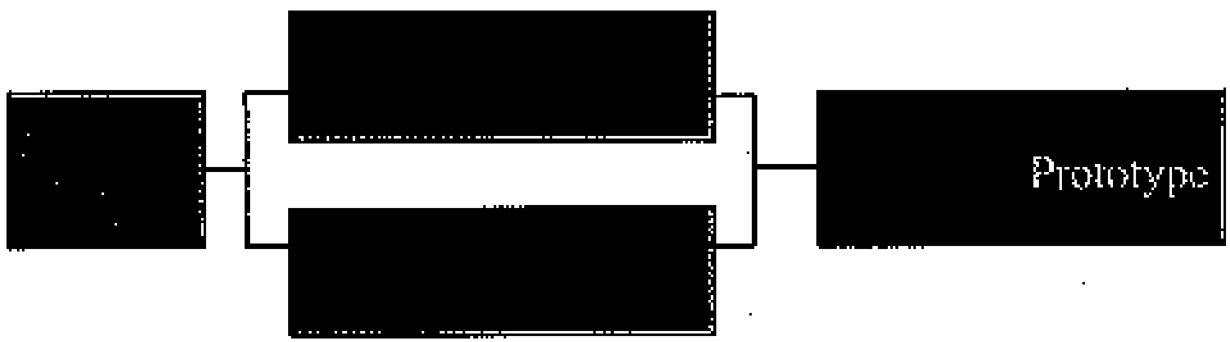
Fuel Technology

S. Hayes	ANL
J. Herceg	ANL
P. MacDonald	INEEL

ATW T&B Roadmap

- 25-year program
- Full-size Prototype ready at conclusion

- Route:

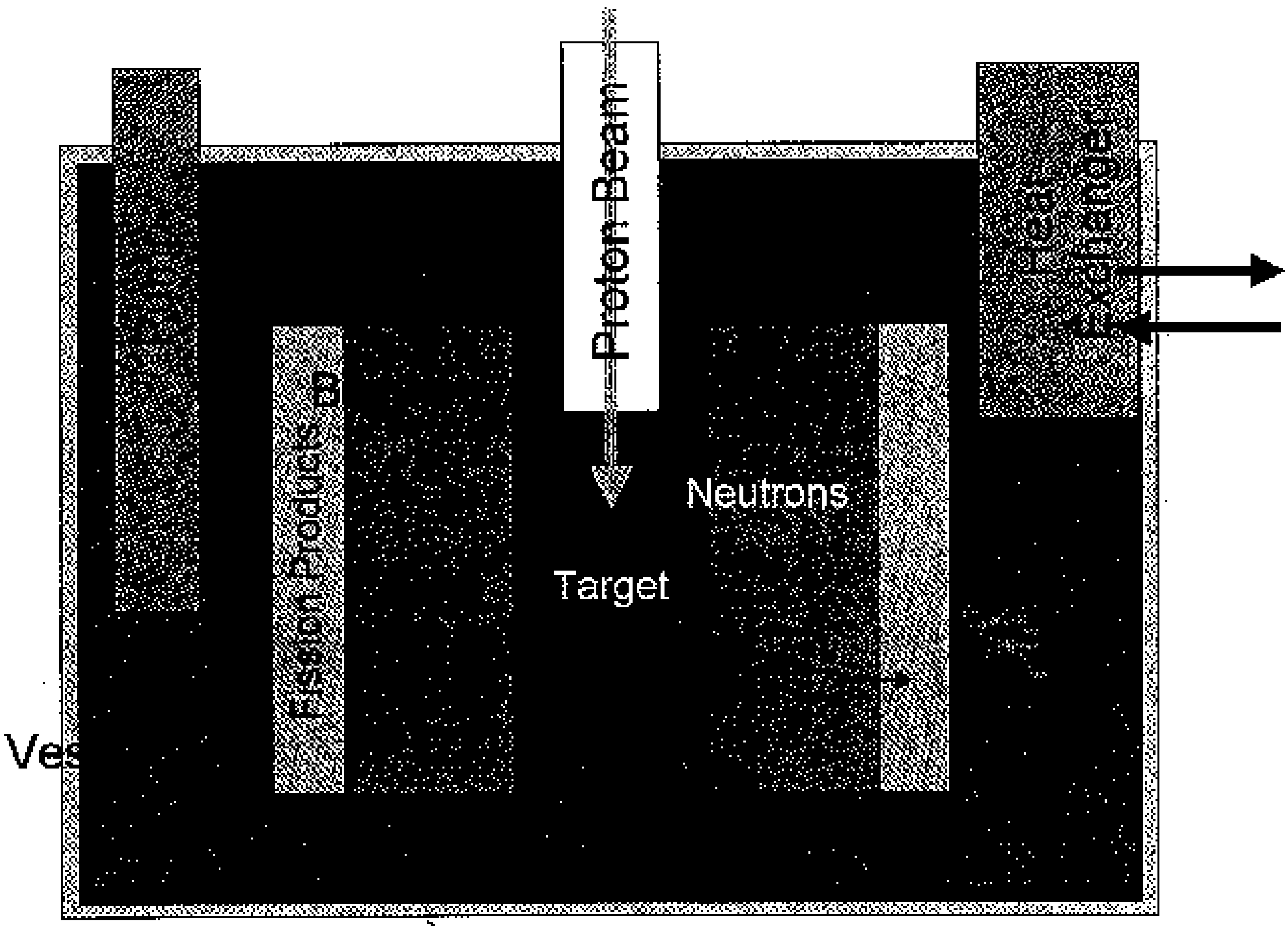


Objectives

- The ATW Target and Blanket (T&B) system is to provide rapid destruction of actinides and efficient transmutation of key long-lived fission products, with minimal production of new waste.

- The T&B Research & Development Program is to produce a fully integrated ATW T&B Prototype module operating at full power, which could be used as a model for ATW deployment by 2025, should the Nation decide to choose that path.

A schematic view of the ATW T&B



Four basic features of ATW T&B Systems

• The source neutrons are generated by direct impingement of the accelerator proton beam onto a target material in a process called spallation. -- 30 Neutrons per GeV Proton

• The spallation neutrons are multiplied in the surrounding subcritical blanket, which contains the actinides and fission product transmutation assemblies. -- Neutron multiplication >20 (k_{eff}>0.95)

• Because significant heat production occurs from fission in the surrounding blanket assemblies, adequate means for heat removal must be present, analogous to critical fission reactors of similar power level. (1000MW)

• Leakage neutrons from the subcritical core are captured in the fission product assemblies, composed of rods containing long-lived fission products, such as technetium and iodine.

Subcriticality facilitates or accelerates tasks that might be more difficult or inefficient in critical systems.

- Subcritical systems do not rely on delayed neutrons for control and power change; they are driven only by the externally generated neutron source.

- Fertile materials are not needed to compensate for the neutronic uncertainties of TRU or provide negative doppler feedback.

- Subcriticality allows use of fertile-free compositions, thereby maximizing the TRU destruction rates and relaxing the required separation efficiencies in the waste treatment steps.

- R&D is required to go from existing Reactor Technology to reliable and efficient Subcritical Systems.

At this stage all the proposed ATW T&B systems are adaptations of existing reactor designs to subcritical operation.

- In general, these adaptations replace the centermost part of the cores with a spallation neutron target and source diffuser.

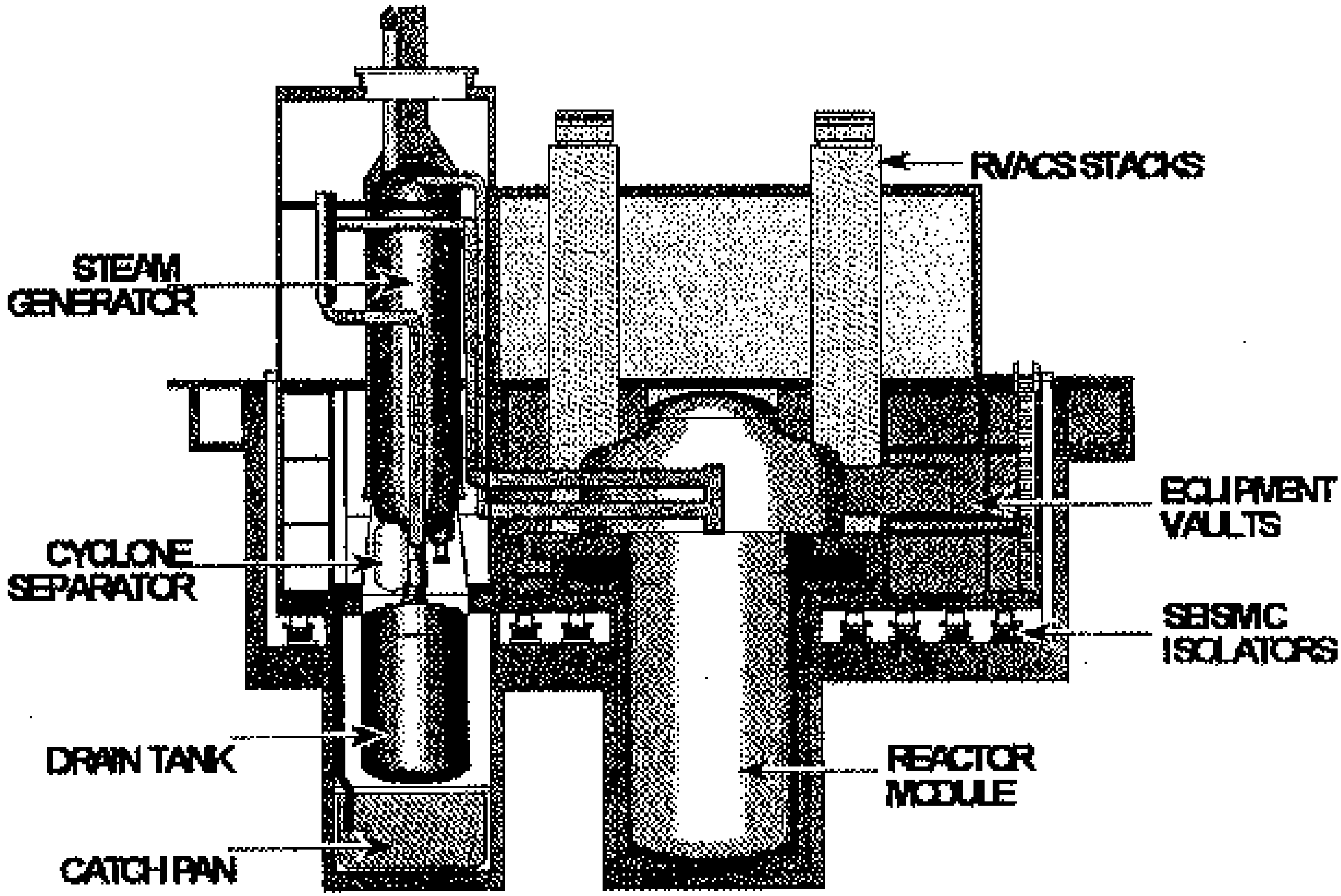
- A vacuum beam tube is used to deliver a proton beam to the center of the core. A window separates the beam line from the spallation target.

- The spallation target can be integral with the core and use the same coolant fluid or separated from the core, with its own cooling circuit.

- The core is divided in multiple fuel regions for shuffling (for more uniform power distribution), and burnable poisons are likely to be used to mitigate the reactivity decrease during burnup.

- Fission product transmutation regions are placed in the reflector volume. Because of the small cross-sections in the fast neutron spectrum, local moderation of neutrons will be required.

The ATW T&B system will resemble a reactor complex



T&B parameters

	ALMR	BRUS-300
Rated thermal power, MW	840	1000
Primary circuit:		
coolant	Na	Pb-Bi
core outlet temperature, °C	499	510
core inlet temperature, °C	360	340
Intermediate circuit:		
coolant	Na	Pb-Bi
temperature at heat exchanger outlet, °C	477	460
temperature at heat exchanger inlet, °C	327	290
Steam generating circuit:		
working medium	water-steam	water-steam
steam capacity, t/h	1889	1200
superheated steam pressure, MPa	15.17	4.0
superheated steam temperature, °C	455	435
feedwater temperature, °C	216	150
Power conversion efficiency	36%	35%
Fuel composition	U-23 Pu-10Zr	Zr-U / UO_2
Core loading, kg	3255	~3750
Vessel	316 SS	
Diameter, cm	917	600
Height	1935	1100

Irradiation Interval (d)	100
Cycle Duration (d)	120
Fuel residence time (cycles)	6

Equilibrium cycle mass flows (kg/y, normalized to 840 MW operation):

Transuranic actinides from recycle	1300
Transuranic actinides from LWR	270
Total transuranic actinides charged	1570
Transuranic actinides discharged	1050
Transuranic actinide destruction	520
Discharge burnup (atom%)	33

ATW Target and Blanket (T&B) Research & Development Program

- The T&B system was divided into subsystems
  - Nuclear Design and Safety
  - Coolant Chemistry and Materials Compatibility
  - Heat Removal and Ancillary Systems
  - Target Technology
  - Fuel Technology

- Reference and alternate technologies identified (as appropriate), and appropriate R&D proposed

T&B Preferred, Reference / Back-up and Alternate Options

- **Preferred:** Solid metallic fuel elements and moderated assemblies for fission product transmutation. LBE coolant, in a single loop configuration as target, coolant and reflector. BRUS-300-derived concept to be considered early.

- **Reference / Back-up:** Solid tungsten target assemblies. Sodium as coolant. ALMR-derived design to be considered early. Cost reference for long-term large-scale implementation.

- **Alternate:** Helium as coolant; not considered in detail in present roadmap, but subject of trade studies during initial phase.

Nuclear Design and Safety

Determine core design features,
Quantify performance characteristics,
Confirm system nuclear safety,
Support licensing.

Specific issues in the Nuclear Design and Safety R&D include:

- Design for degree of subcriticality
- Accommodation of burnup reactivity loss
- Accommodation of feed composition variation with recycling
- Long-Lived Fission Products (LLFP) incineration strategy
- Determination of dynamic behavior
- Safety analysis and confirmation
- Validation of simulation tools

Coolant Chemistry and Materials Compatibility

Determine coolant operating conditions
Select compatible structural materials
Extend coolant technology to spallation environment
Determine coolant system safety
Develop waste management strategy

Specific issues in the Coolant Chemistry and Materials Compatibility R&D include:

- Coolant conditioning,
- Cover gas control,
- Fuel and structural materials corrosion in coolant,
- Structural materials performance,
- Heat removal
- Waste management.
- Effect of protons and spallation products on coolant chemistry, materials compatibility
- Technology transfer

Heat Removal and Ancillary Systems

Confirm system safety,
Develop technology to allow fabrication of components for Demo systems

Modeled on US experience in the development of heat removal and ancillary systems for sodium-cooled systems - Liquid Metal Fast Breeder Reactor (LMFBR), Advanced Liquid Metal Reactor (ALMR)

Successful transfer of LBE Technology (preferred option) from Russia assumed

Successful transfer of recent Sodium Technology (back-up option) from France and Japan assumed.

The proposed program includes development of the following components :

- Primary and secondary pumps
- Intermediate heat exchanger
- Steam generator
- Vessel features, such as head, support structures, and fuel handling equipment
- Ancillary systems such as coolant cover gas system and cold trap and filter

Target Technology

Develop suitable spallation target configuration
Select and certify target materials, esp. for windows
Quantify target performance and lifetime

Preferred Technology is LBE target integral with primary loop (hot window concept)
Back-up technology is Tungsten target cooled by sodium
Alternatives are Tungsten target cooled by helium, and separate LBE target (windowless concept)

Proposed R&D Approach:

- Selection of candidate materials
- Proton irradiation of materials in LANSCE insert
- Collection of new and existing physics data into cross section databases
- Determination of target design criteria
- Evaluation of thermal performance of concepts
- Integral testing of target prototypes in Target Test Facility at LANSCE

Fuel Technology

Develop and qualify fuel and fission product transmutation form(s) that meet(s) ATW objectives

Preferred Technology is metal fuel due to pyroprocess compatibility and favorable safety properties

Reference Fuel Form: TRU-Zr alloy fuel particles dispersed in Zr-based matrix

Metal Fuel Alternative: Injection cast TRU-Zr alloy

Non-metal Fuel Alternative(s): TBD

Fission Product Transmutation Form Reference: Tc in noble metal alloy and I as NaI powder

- Issues and Tasks
  - Fabrication technique (retention of volatile actinides and remote implementation)
  - Fuel performance
- Proposed R&D Approach
  - Determine feasibility early with property tests, fabrication studies, and simple irradiation tests
  - Assess irradiation performance in integral rods tests in fast flux (and in LBE coolant for LBE option)
  - Qualify fuel forms in stage-wise fashion as appropriate for Demo units

ATW Target and Blanket (T&B) Development Program

- **Trade Studies and Base Technology R&D (2001-15)**
  - Two-year period of trade studies on system and technology options
  - Addresses technology transfer, conceptual component design, development of materials database, and feasibility issues specifically related to implementation in subcritical systems and will finalize important design choices.
  - Decisions on the fuel, target and coolant technology for ATW DEMO in 2008
  - Confirmation work on ATW fuel will continue until 2015.

- **Demonstration and Large-Scale Integration (2006-25)**
  - Activities directed toward integrated ATW Demonstration Facility (ATW Demo) begin in 2006.
  - ATW Demo to begin operation at low power level (30 MW) in 2015. Power slowly increased, up to full power (850 MW) with ATW-type fuel in ten years (2025).
  - At full power in 2025,the ATW Demo becomes the ATW Prototype, and in addition to demonstrating the operability of ATW it will be used to quantify ATW economic performance and determine ATW infrastructure requirements.

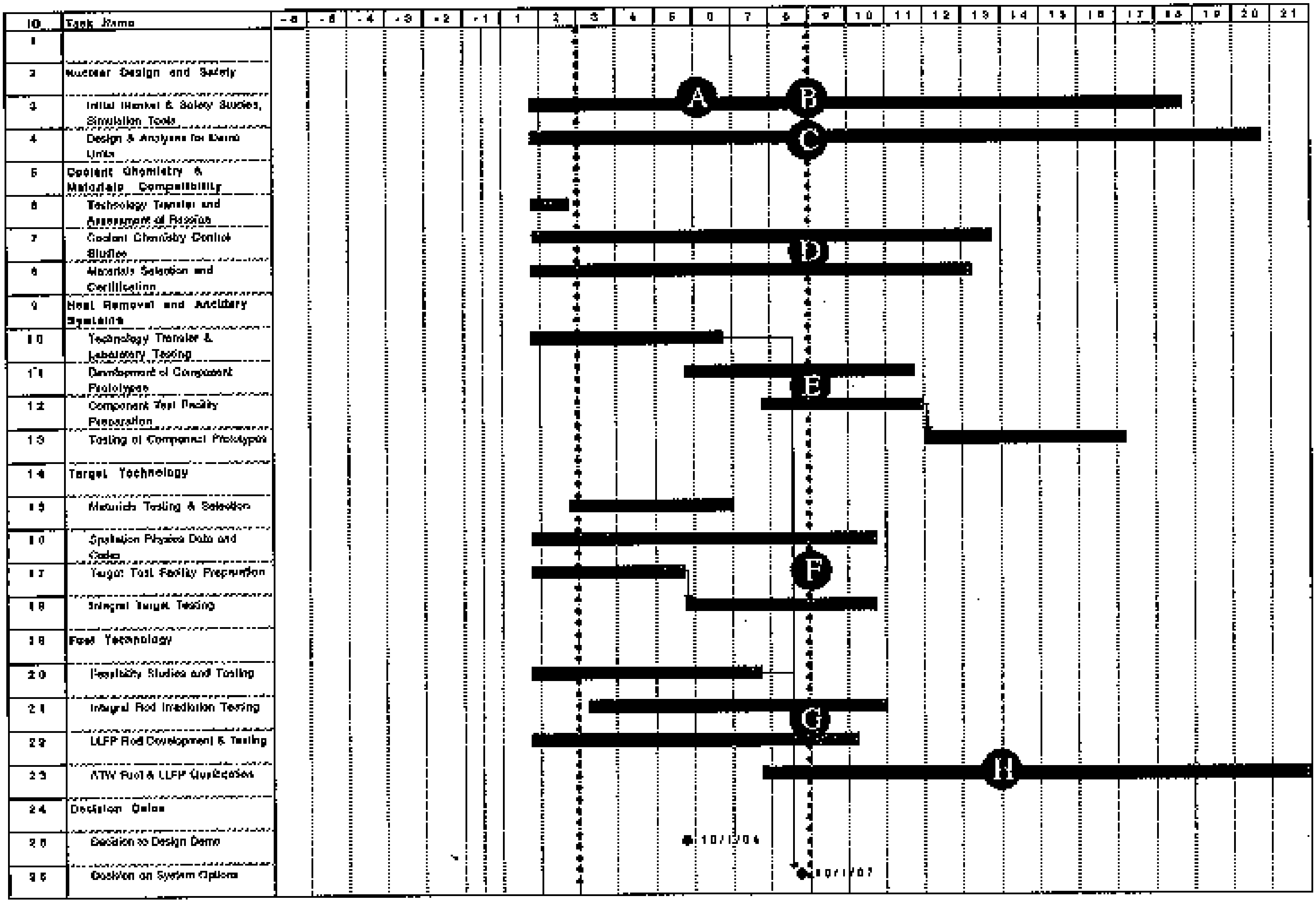
Milestones for the Trade Study Phase

A series of trade studies are required to address the following parameters:

- choice of technical concept (comparison of various subcritical concepts)
- choice of technologies (e.g., coolant and fuel types; target design; system control)
- choice of technical parameters (e.g., fuel composition, maximum fuel burnup, core reactivity level, etc.)
- system performance (actinide and fission product burning and separation rate)
- overall reliability
- size of individual burner unit
- system deployment rate
- efficiency of electricity production

Milestone: all initial trade studies needed to define the system design choices, options, and R&D needs, must reach preliminary conclusion after one year.

ATW T&B RD&D Plan



Milestones of the R&D Phase: Fulfillment of the R&D milestones will allow for the licensing, design, and construction of the ATW T&B Demonstration Facility by year 16.

A - The Safety approach to ATW Operation and Licensing issues will be identified within 4 years

B - Safety modeling tools and analyses required for Title II design of the DEMO Plant established after 8 years

C - A complete set of validated codes will be completed for use in the design of the Demo facility after 8 years.

D - All R&D tasks required to demonstrate the coolant technology will be confirmed after 8 years.

E - Engineering capabilities and design expertise to construct thermal-hydraulics components available by year 8

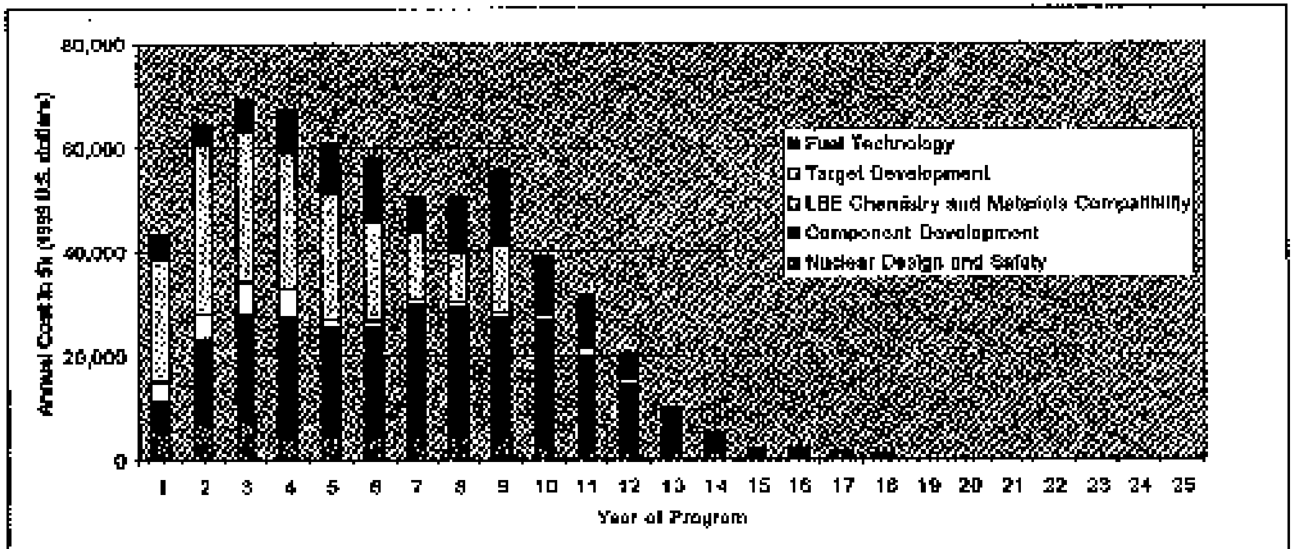
F - A demonstrated target concept, with choice of window material, will be ready after 8 years.

G - Fuel properties and behavior tests will be completed within 8 years in order to provide data for the final Safety Analysis of the Demonstration burner operating at low power with uranium fuel.

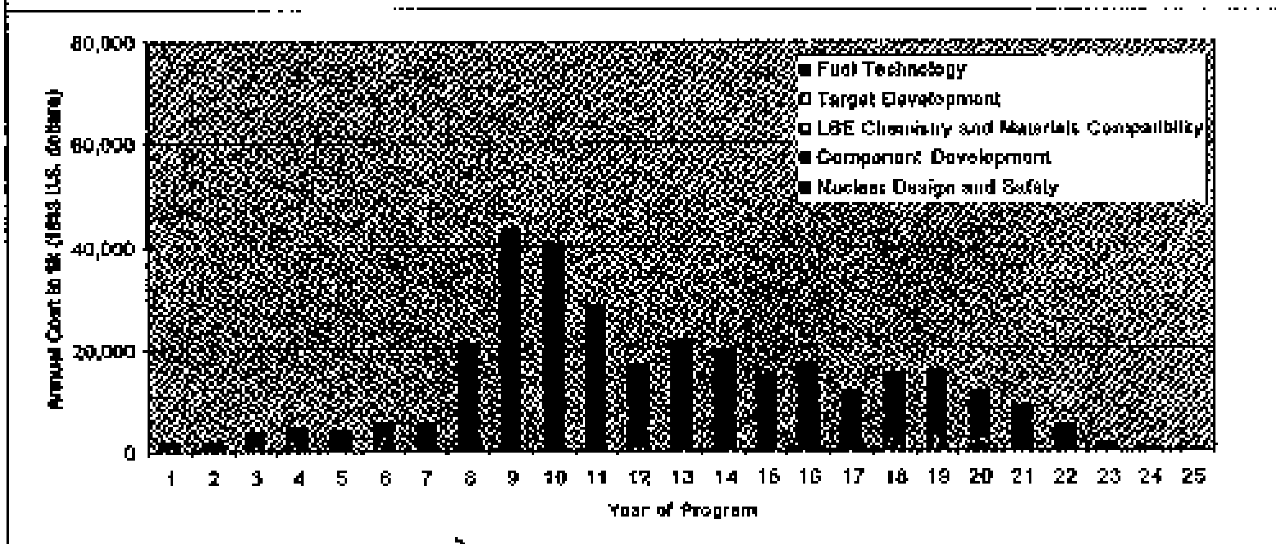
H - Fuel properties and behavior tests will be completed within 13 years in order to provide data for the final Safety Analysis of the Demonstration burner operating at 420 MWth with the ATW fuel form .
These data comprise:
- -fuel thermodynamic properties
- -fuel/clad/coolant compatibility demonstration
- -fuel irradiation behavior

All R&D tasks will be continued at a reduced level after completion of the milestones. Feedback from other R&D programs and from facility operations will be used to optimize the processes.

Estimated Cost of Proposed ATW T&B Development



R&D Costs



E,D&D Costs

Concluding Remarks

- We have prepared a Roadmap for the development of the ATW T&B, aimed at full scale implementation in 25 years.

- The technologies identified are adaptations or extensions of critical reactor technologies, with R&D and tech. transfer required in all cases.

- We have identified Preferred, Reference, and Alternative Options to be investigated during the course of the Trade Study and R&D phases.

- With the appropriate allocation of resources, we believe the approach will be successful in the indicated time frame of 25 years.