Beyond the Fusion Island: Wider Engineering Challenges Session 3: Enabling Technologies

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 Image: Second system
 Image: Second system

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EPRI...Born in a Blackout

Independent, nonprofit center for collaborative public interest energy and environmental research.

International membership and reach

- Nearly 40 participating countries participate in research, development, and demonstration activities
- International members > 25% of EPRI research (> 50% for nuclear)
- EPRI members generate > 90% of the electricity in the United States (100% of US nuclear)

Together...Shaping the Future of Energy®



EPRI Research & Development





Driving thought leadership, advanced R&D, and technology scouting and incubation to sustain a full pipeline of solutions





EPRI's Return to Fusion

- Fusion technology scouting over past 15 years
- Expanding engagement fusion community and stakeholders
- Fusion Industry Association affiliate membership
- Internal funding of fusion-related activities
 - Staff training
 - Fusion Forum interest group
- Formal stand-alone fusion R&D program and offerings under development for 2023+



AP-2254 Research Project 1413-1

Topical Report, February 1982

Prepared by

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> Principal Investigator R J Vondrasek

> > Prepared for

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> EPRI Project Manager N A Amherd

Fusion Power Systems Program Advanced Power Systems Division

Key Elements for Commercial Fusion

- Fusion demonstration (net energy, fuel supply, etc.)
- Reasonable licensing path
- Coupling to power conversion

 (or other balance-of-plant systems for non-electric missions)
- Reliable energy generation and realistic maintenance

Business case and economic competitiveness

Not specific or necessarily unique to fusion









Most of the Plant Lies Outside the Fusion Island



Convention Nuclear (Fission) Cost Drivers



Capital intensive energy generation projects share many attributes.



Enablers for Schedule, Cost, and Risk Reduction



These are active research areas for EPRI and industry...for a reason!



Digital Transformation of Project and Asset Management Across Entire Lifecycle



Model Based System Engineering

- Models represent all plant aspects during design, construction, O&M and decommissioning
- Leveraging of a fully integrated digital ecosystem improves quality, schedule and costs <u>over entire plant lifecycle</u>
- Eliminate paper-based systems and use common digital information platform as the single source of truth across all applications and disciplines



Realizing MBSE Value via Digital Twinning





Advanced Materials and Manufacturing (Major Investment Focus Across Energy Technologies)



Adv. Fission Materials Development Approach



EPR



- Four categories of development needed:
 - <u>Materials properties to support initial design</u> obtain ASME acceptance for constructions including high temperature & time-dependent properties
 - <u>Materials' response in environment</u> effects of environment on mechanical behavior in addition to corrosion resistance
 - <u>Response to neutron irradiation</u> effects of realistic levels of irradiation on microstructural & property stability
 - <u>Confidence in Supply Chain</u> material manufacturers → major component OEMs → EPCs → Operators

					ADVANCE	D REACTO	R MATERIALS	DEVELOPMENT ROAD	MAP
OVERVIEW		REACTOR TYPES		MATERIA	L TYPES		ROADMAP	GLOSSARY	
ROADMAP OVERVIEW	STAINLESS STEELS	FERRITIC-MARTENSITIC & LAS	NICKEL-BASED ALL	OYS GRAPHITE	& CERAMICS	CORROSION	CLADDING	DISSIMILAR METAL WELD EXPLORATORY ALL	LOYS
ROADMAP Austenitic Stainless Steels									
TECHNICAL TOPIC	2021	2022	2023	2024	2025	2026	2027	Example Page	
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D9 Stainless Steel				Code qualificatio Div 5 for D9 incl	on properties for A uding time depend	SME code Sec III lent propertie			
						Evaluate resistar	nce to irradiation/swelling	at high dpa for D9 SS	
CF8C-Plus	Code quali Div 5 for C time deper	Code qualification properties for ASME code Sec III Div 5 for CF8C-Plus cast & wrought forms including time dependent properties							
			Corrosion behavior of CF8C-Plus Evaluate resistance to irro			nce to irradiation/sv	velling at high dpa for CF8	3C-Plus	
In Progress									
Extend Code Properties Mechanical / Code Properties		Corrosion Properties		Irradiation Properties		Near-Term Data C	Capture Other		

Advanced Manufacturing Methods

(in process of demonstration & qualification for fission applications)

- Powder Metallurgy-Hot Isostatic Pressing: PM-HIP
- Directed Energy Deposition AM: DED-AM
- Powder Bed Fusion AM: L-PBF or EB-PBF
- Advanced Cladding Processes:
 - e.g., diode laser cladding, hot wire laser welding, friction stir additive, cold spray & laser assisted cold spray, PM-HIP
- Electron Beam Welding: EBW
 - For large components (RPVs, SGs, pressurizers, fusion components, etc.) _
- Other AMMs of interest:
 - Additional advanced welding technologies, cold spray, machining techniques, surfacing technologies













Demonstrations: Advanced Manufacturing for SMRs

- Powder Metallurgy Hot Isostatic Processing
 - Produces near-net shaped components
 - Eliminates 1000's of hour of machining
 - No welds to inspect
 - Forging: 2-5yr lead time; PM-HIP component produced in 6-12 months
- Electron Beam Welding
 - 10x reduction in typical weld times
 - Demonstrate EBW by fabricating reactor sections
- Diode Laser Cladding
 - Reduces cladding material by > 50%
 - No machining required after application
- 40% Cost Reduction Potential









Representative Model of NuScale Reactor Vessel

DOE Project DE-NE0008629

ASME Code Qualification: Additive Manufacturing



316L LPBF ASME Section III Code Case

- Submitted in August 2020
- Currently under review by ASME
- 316L Gas Metal Arc DED-AM ASME Section III Code Case
 - Builds complete and material testing and characterization under way
- 316L Powder Blown Laser DED-AM
 - One valve complete
 - Material testing and characterization under way







The Business Case as the Ultimate Enabler



Fusion Beyond Electricity



Fusion energy can compete in markets beyond the practice of generating baseload electricity to supply the electric grid.



Fusion-Fission-Renewables Integration



Together...Shaping the Future of Energy®