

US Blanket Facilities Anticipated for Fusion Pilot Plant Preparation

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Blanket Roadmap Toward a Fusion Pilot Plant

Topical Thrusts

Helium Cooling & FW PFC Development

Solid Breeder Development

Liquid Breeder (PbLi) Development

Functional Material Development

Blanket Design and Integration

Adv RAFM Material Development

Tritium Extraction from Blanket Fluids

Tritium Behaviors in Blanket Materials

Hydrogen Separation from Plasma Exhaust

Tritium Behaviors in Plantwide Systems

Integrated Testing

Blanket Component Test Facility (non-nuclear)

Fission Neutron Testing of Blanket Surrogates

Fusion Neutron Testing of Materials (test assemblies?)

Tritium Fuel Cycle Test Assembly

Fusion Pilot Plant



Things have become COMPLEX in the US Fusion Program

The introduction of private entities into fusion space will potentially change how and what research we do, since the government is favorable to public-private partnerships

Public R&D will be the focus of this short description, however, private entities are pursuing different fusion configurations and blanket concepts

Already there is a public-private interaction at a smaller scale for Nat'l Labs to help private entities

Milestone-based programs are expected in the near future

Without a TBM program, we must develop infrastructure for the Fusion Pilot Plant (FPP) directly

A typical evolution from single-few effects toward higher integration is anticipated

Helium Cooling & FW PFC Development

Blanket cooling (cooling enhancements, manifold and distribution)

} **Helium forced flow loops**
HHF apparatus
Detailed CFD, expt'l validation

Solid Breeder Development

Solid breeder compounds (Li – Be – M – O, Li – M – O),
Non-nuclear behavior
Helium purge gas and tritium recovery
Irradiation response
Manufacturing, form and geometry

} Material simulations, and material production
Mech, high temp, hydrogen transport, corrosion
Helium purge gas loop
Fission & ion irradiations (maybe fusion irradiation)
AM or other, pebbles to cellular

Liquid Breeder Development

PbLi corrosion and compatibility
PbLi thermo-fluids MHD
PbLi heat exchanger
PbLi cleanup and stoichiometry control

} **Thermal convection loops**
Thermo-fluids and corrosion forced flow loops
Materials/PbLi compatibility
Fluid cleanup assembly (polonium control)
Fission irradiation
PbLi CFD/MHD, energy and mass transport simulations

Functional material development

SiC, flow channel insert
N-multiplier
Corrosion coating
Tritium barriers
Electrical or thermal insulators

} Material manufacture, form, geometry
Fission & ion irradiation (maybe fusion irradiation)
Application techniques
Testing in appropriate environments
Assembly and integration

Blanket Design and Integration

Thermo-mech and property evolution
He CFD
LM CFD/MHD, heat and mass transport
Tritium Migration
Electromagnetics-mech
Neutronics
Thermal hydraulics
Multi-physics frameworks

High performance workstations
High performance large node or clusters
National resource computing (NERSC)
Cloud computing
Leading edge computing (very large problems)

Adv RAFM Material Development

Cast Nano-Structured Alloys
Oxide Dispersion Strengthened

Manufacturing, treatments, welding, joining, qualification
Fission and fusion irradiation, and characterization

Tritium Extraction from Blanket Fluids

Vacuum permeator (others?)
PbLi
He (coolant and purge gas)
FLiBe

Hydrogen permeation apparatus/flow systems
Window material characterization, lifetime
Scaleup to large throughput

Tritium Behaviors in Blanket Materials

Various materials diffusivity, solubility, trapping, etc.
Sensitivity to fluid and solid impurities, surface conditions
Irradiation responses
FW plasma interactions

UHV Permeation and TDS apparatus
Surface characterization apparatus
Fission and ion irradiation, in-situ observations
Linear plasma device, need FW-specific loading

Hydrogen Separation from Plasma Exhaust (direct internal recycle)

Super permeable membranes
Cryo-trapping
Standard permeators

Plasma/gas source, vacuum
Cryo-vacuum
Permeation test chamber
Fueling-exhaust chamber circulation apparatus

Tritium Behaviors in Plantwide Systems

Physics of apparatus behaviors in tritium loops
Reduced models of apparatus and loop behaviors
Directed improvement of individual apparatus and strategies
Tritium measurements, accountability, and control
Tritium permeation barriers, capture technologies, impacts on materials, and assessment of losses
Plantwide tritium management, meeting release limits

Wide range of tritium apparatus subsystems (loops)
Simulations, process and time-dependent
Hydrogen laboratories for testing

Recap of Blanket “Facilities or Capability” Required in Advance of the Most Integrated Testing Facilities and the Fusion Pilot Plant

Pre-requisite Testing Facilities

Helium Forced flow loops
HHF apparatus
Helium purge gas loop

Solid breeder non-nuclear lab
Manufacturing (AM) facility

PbLi thermal convection loops
PbLi Forced flow loops
PbLi cleanup and auxiliary assembly

Hydrogen (tritium) permeation, behaviors, and flow lab (scaleup), UHV
Linear plasma or similar

Fission irradiations & characterization
Ion irradiations
Fusion irradiations

Fueling/exhaust circulation system

Multi-faceted tritium apparatus and flow subsystems lab

Significant design/simulation activity and computing platform capability

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