Power Plant Team Members

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PoP Studies (2003 through 2009)

Spatial Volume	Time Scale (Phenomena Duration)			
	Nanosecond **(Target Gain)**	Microsecond	Millisecond **(Rep. Rate)**	Quasi-Steady **(Safety/ Reliab.)**
Capsule	Neutron/ion/ x-ray emission	Target debris expansion/ interaction with ablation debris, venting, impulse	—	—
Hohlraum (if used)	X-ray and debris emission distributed by speed			Material Recycle and Makup
Driver energy transport paths		—	—	RTL Weight
Pocket Void/Vent Paths	—	—	—	—
External Condensing Region	—	—	—	—
Target-facing Surface Layers	—	—	—	—
Blanket (liquid)	Neutron and gamma deposition	Neutron heating relaxation	Liq. hydraulics/ solid thermal mechanics	Activation, neutron damage (solids), safety,
Volutes	—	Debris Deposition Debris Deposition	"Slow" Debris Deposition	Damage rate
Chamber structures	Neutron and gamma deposition	—	—	Safety, tritium, activation, corrosion, redundancy
Coolant recirc./heat recovery loop	—	—	—	
Accelerator/laser systems	Driver physics	—	Driver rep. rate and reliability	
Target/RTL Insertion	RTL Stability	—	—	RTL Weight, Closure, Insertion, Debris Accum.
Target/RTL fabrication	—	—	—	Safety/ reliability, Maintenance, Recycle
Balance of plant	—	—	—	Safety/ reliability

Legend
Next Step
Issues Important to Z - Pinch Plant
Issues Shared with Community

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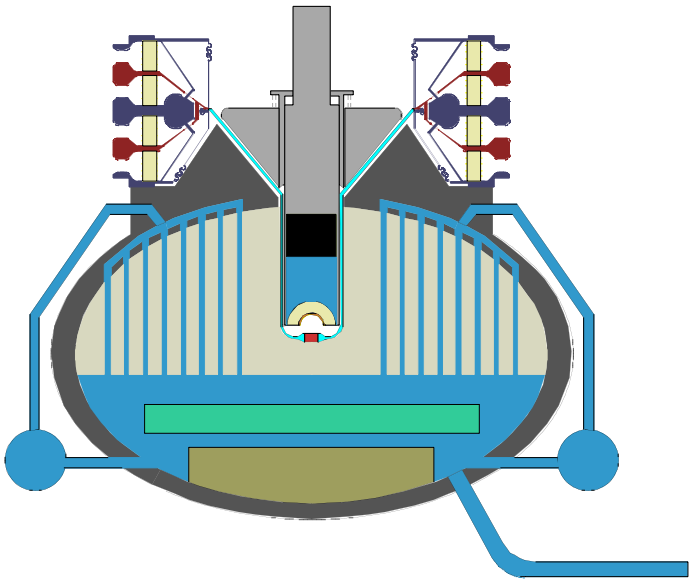
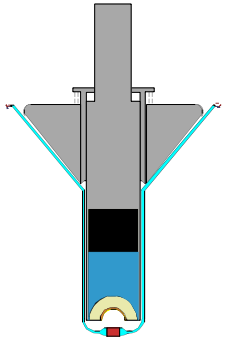
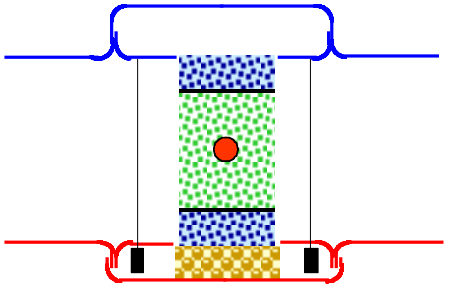
Z-Pinch Power Plant General Concept



Cartridges containing fusion capsules are repetitively inserted, ignited and burned in a dynamic hohlraum driven by a shaped 150 ns rise time 60-100 MA pulse connected through a recyclable transmission line.





Current Objective:

Refine one preliminary concept of a Power Plant utilizing Inertial Fusion Energy driven by a pulsed power z-pinch x-ray source and define a development program.

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Z-Pinch Power Plant
IFE through lower technology approaches

Advantages

- Elimination of spatial standoff requirements
- No vacuum requirements in the crucible
- All components are mechanically aligned
- High fusion yield per shot
- Low repetition rate
- Magnetohydrodynamic direct conversion possible
- Low driver cost (~$20/Joule)
- Major components survive for plant operational life (30-40 yrs)

Disadvantages

- Manufacturing requirements are intensive
- High yields challenge crucible strength and containment

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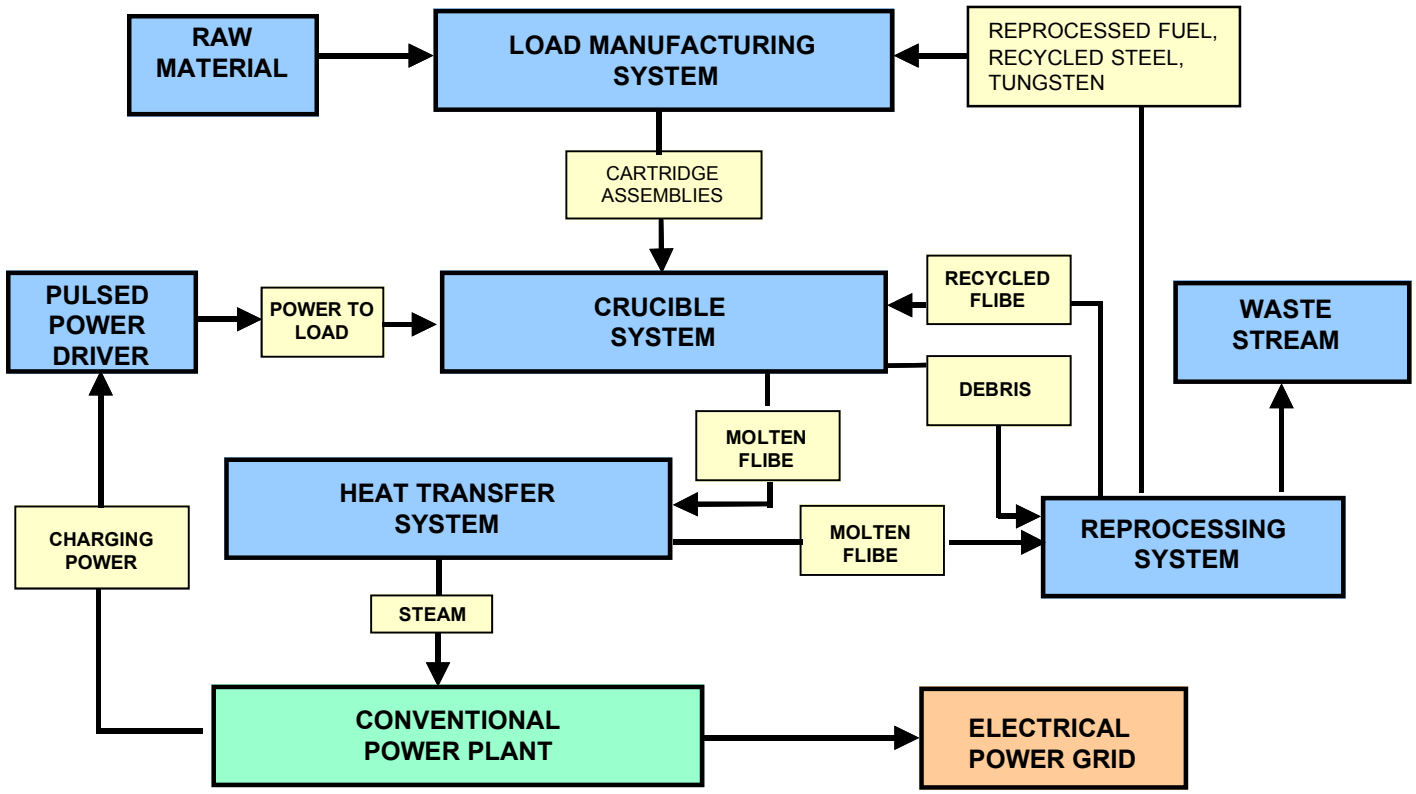
Z-Pinch Power Plant
Preliminary Concept Details

ZFE SYSTEM STUDY PROCESS FLOW DIAGRAM



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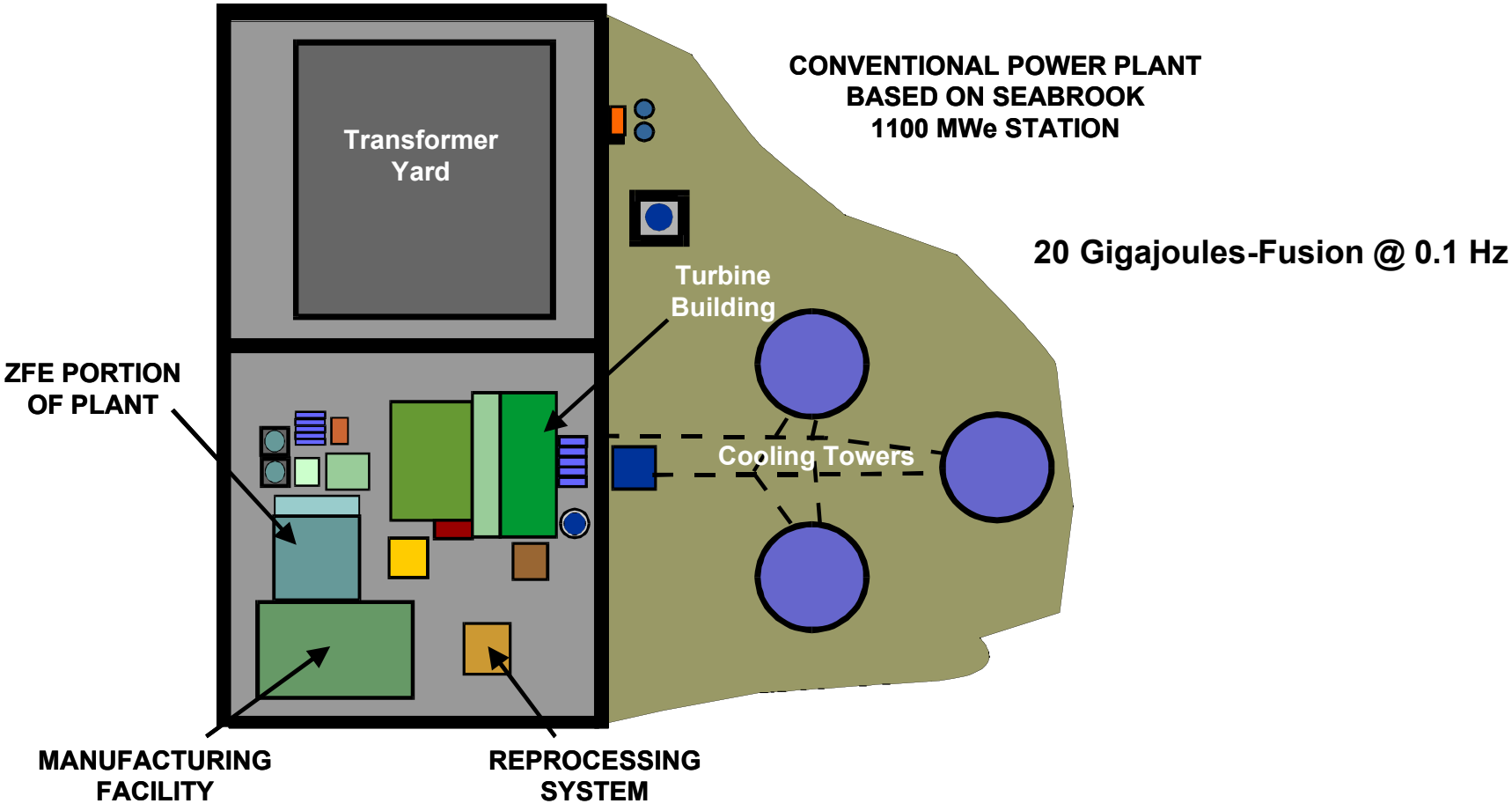
Z-Pinch Power Plant
Conceptual Plant Layout



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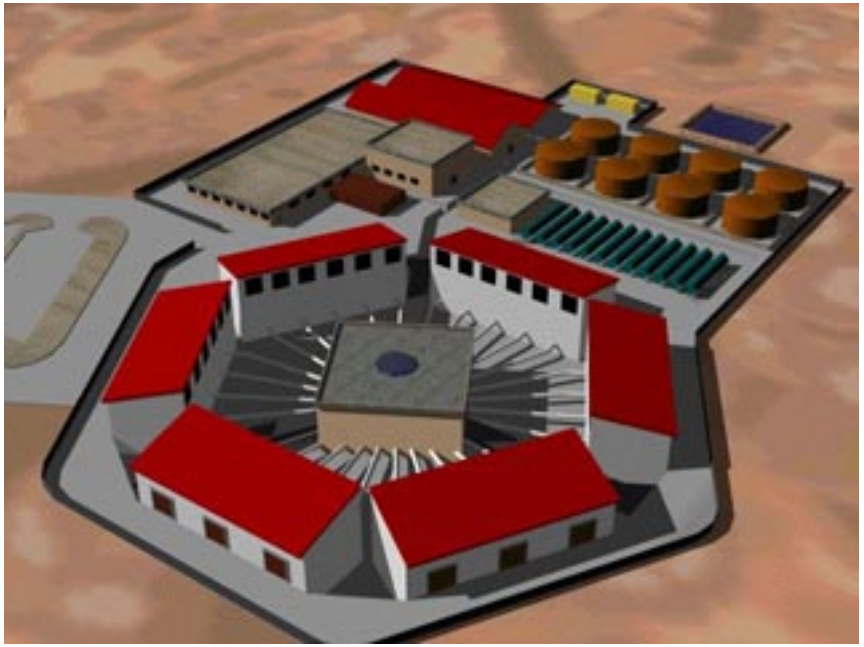
Z-Pinch Power Plant
Pulsed Power Driver Details



Proposed X-1 Research Facility concept at 60 MA

- **X-1 High Yield Baseline**
- **X-ray Driver**
  - **16 to 20 Megajoules**
  - **1000 Terawatts**
- **Projected Yield of 1 to 3 Gigajoules**
- **Repetition Rate of 0.1 Hz**
- **Issues to be explored**
  - **Repetitive Pulse Mode**
  - **Recyclable Transmission Line Optimization and Installation**
  - **Maintenance of Pulsed Power Systems**

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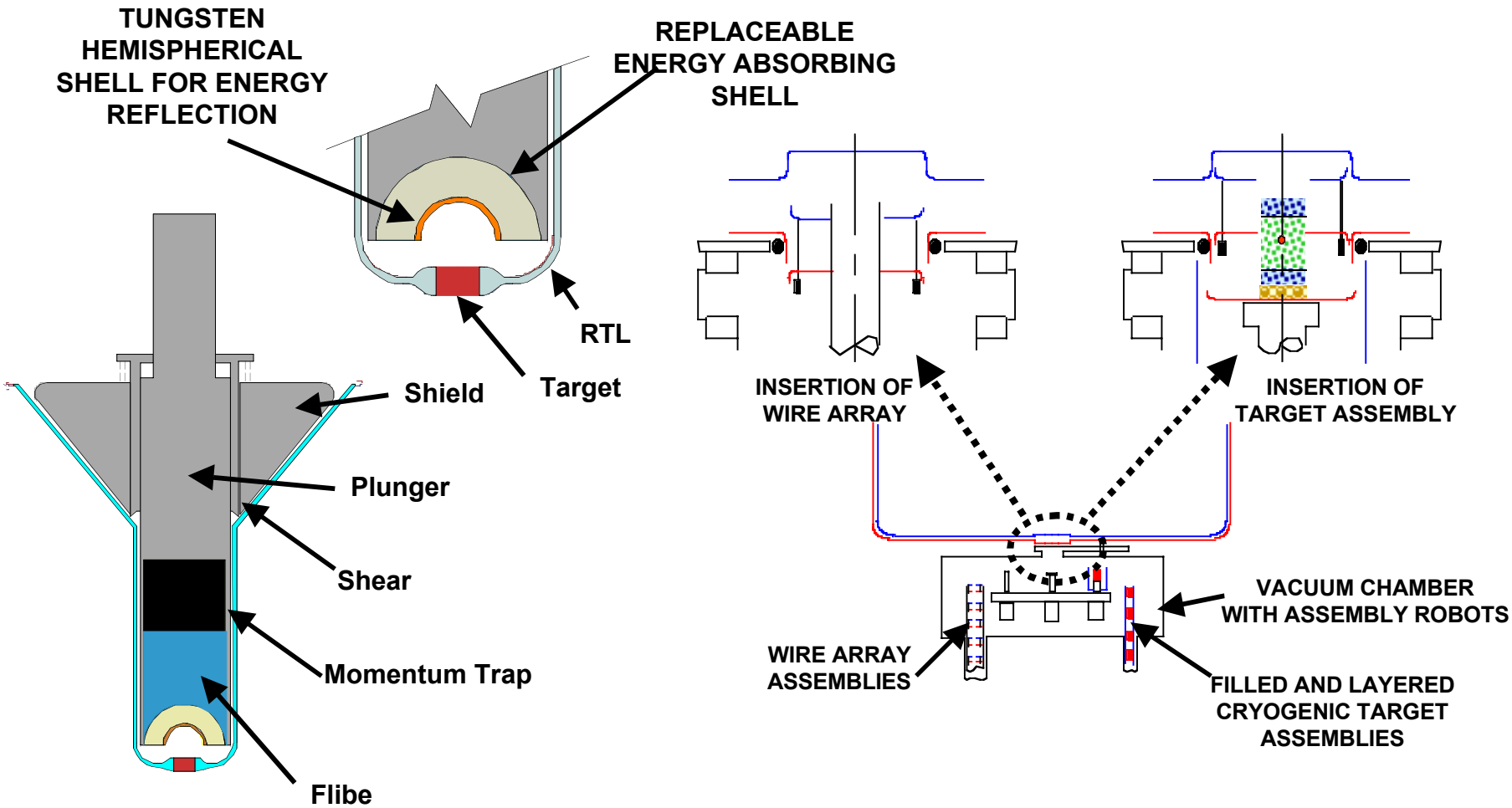
Z-Pinch Power Plant
Cartridge Details



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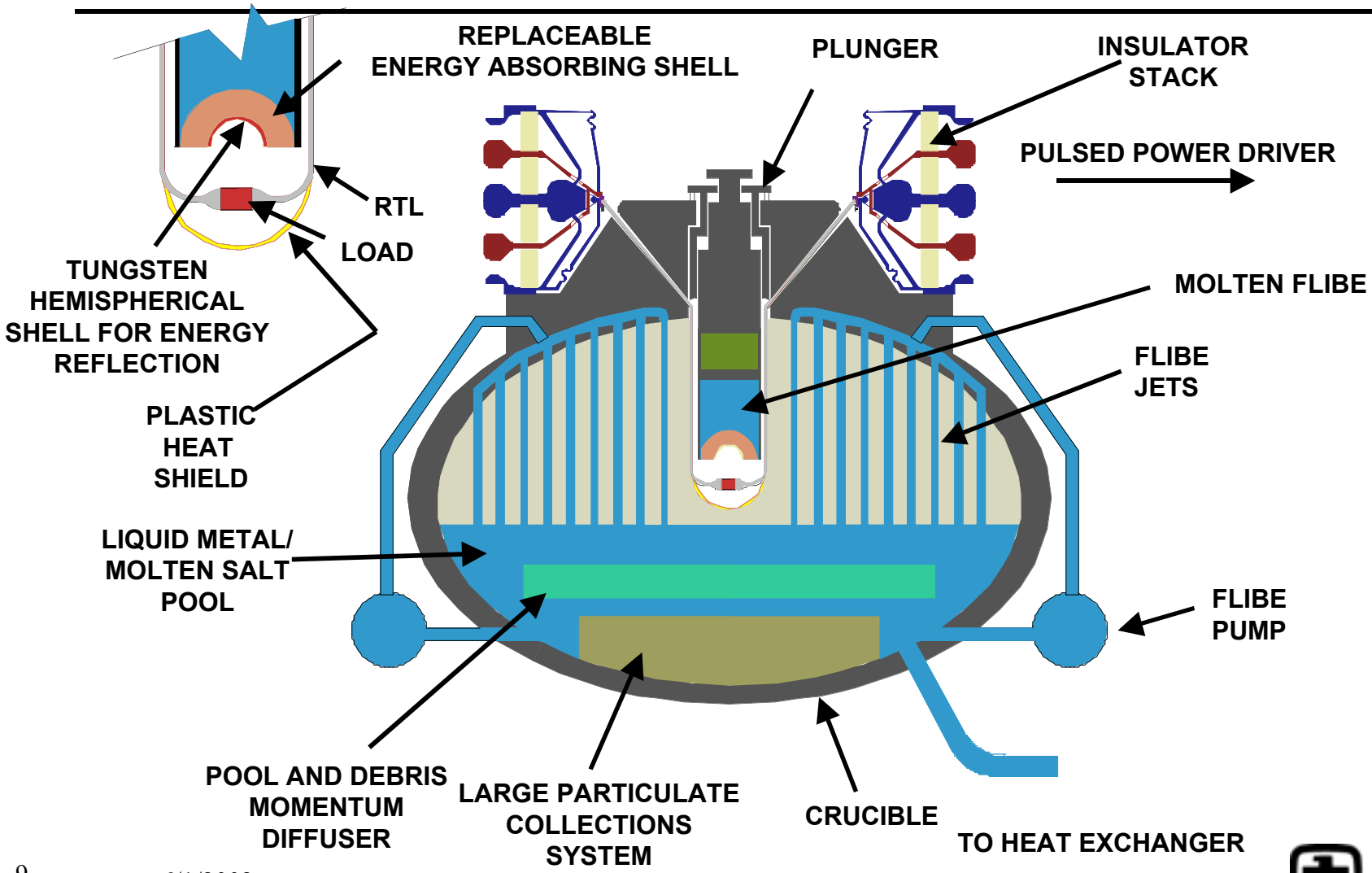
Z-Pinch Power Plant
Crucible Details



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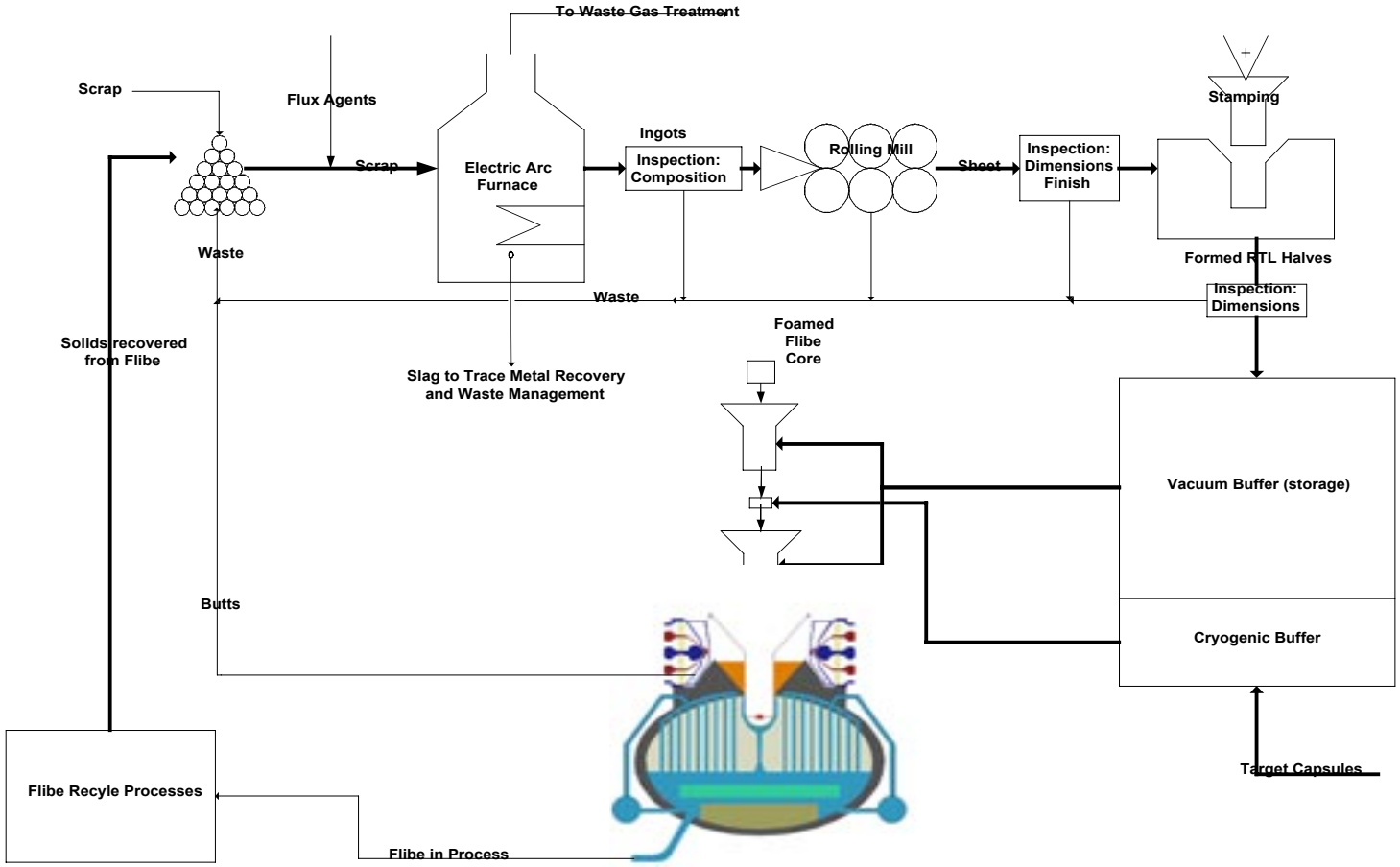
RTL Manufacture Process



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Z-Pinch Power Plant
Crucible Operational Cycle

Movie of 10 second

Operation of a

Z-Pinch Power Plant

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Z-Pinch Power Plant
Details of Cartridge Insertion

Close-up Movie

Of Vacuum Connection

and

RTL Shear

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Z-Pinch Power Plant
Blanket and RTL Materials

- **The primary goal for materials selection is to permit simple mechanical separation of target and blanket materials**
- **Lithium is required for tritium breeding, but is chemically reactive.**
- **Baseline design:**
  - **puts lithium in a chemically-stable molten salt phase (Flibe) that can be pumped**
  - **selects carbon steel (minimized impurities) for conductor phase, since it has low long-lived activation and precipitates from Flibe as a solid that can be recovered by filtering**
  - **selects tungsten as the high-Z material since it has low long-lived activation and can be recovered chemically from the steel phase**

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A Z-Pinch Power Plant Containment Details

- Flibe has good shielding characteristics
- 0.4 m equivalent thickness of Flibe is needed to make steel crucible wall and vacuum insulator lifetime components
- Larger thickness of 1 m required to achieve Tritium Breeding Ratio of 1.1
- Overall energy multiplication is 1.1
- Less than 10% of the energy is deposited in crucible wall

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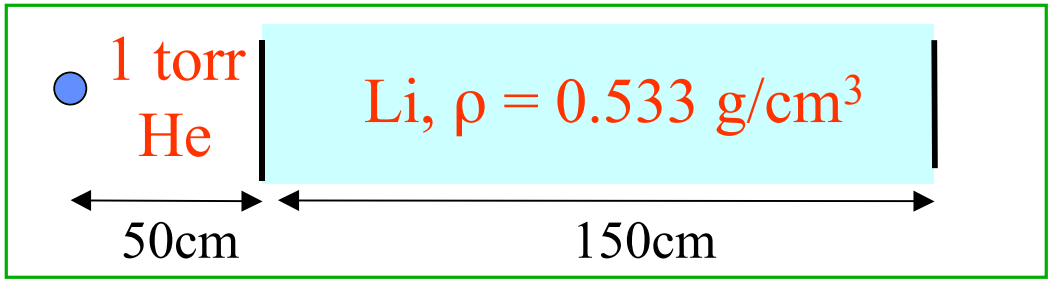
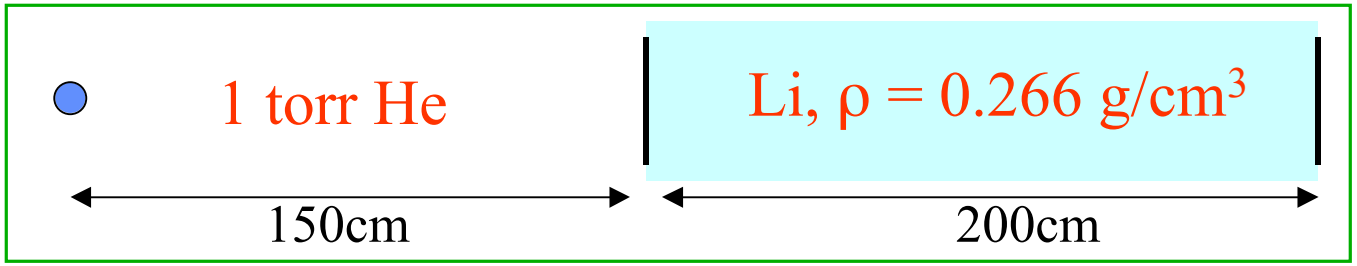
Z-Pinch Power Plant
BUCKY calculations for Lithium

- 1-D spherical geometry
- 1GJ total Yield, ~900 MJ in x-rays, ~100 MJ in Pb ions
- Chamber interior temperature – 600°C

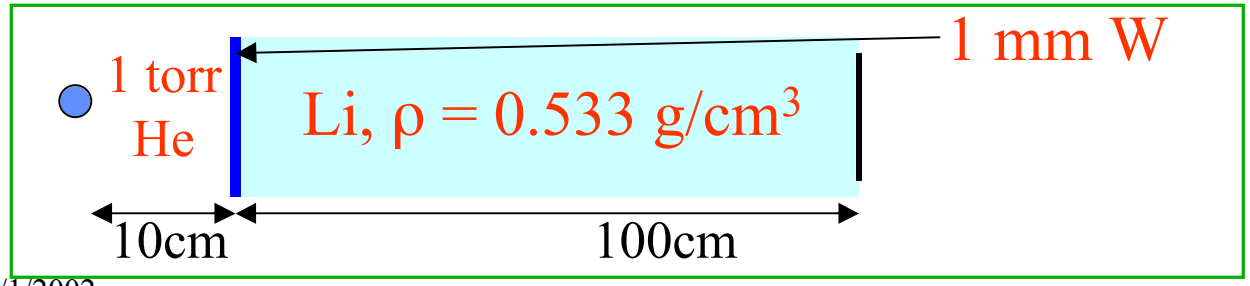
Bottom Pool



Side Walls



RTL Filler



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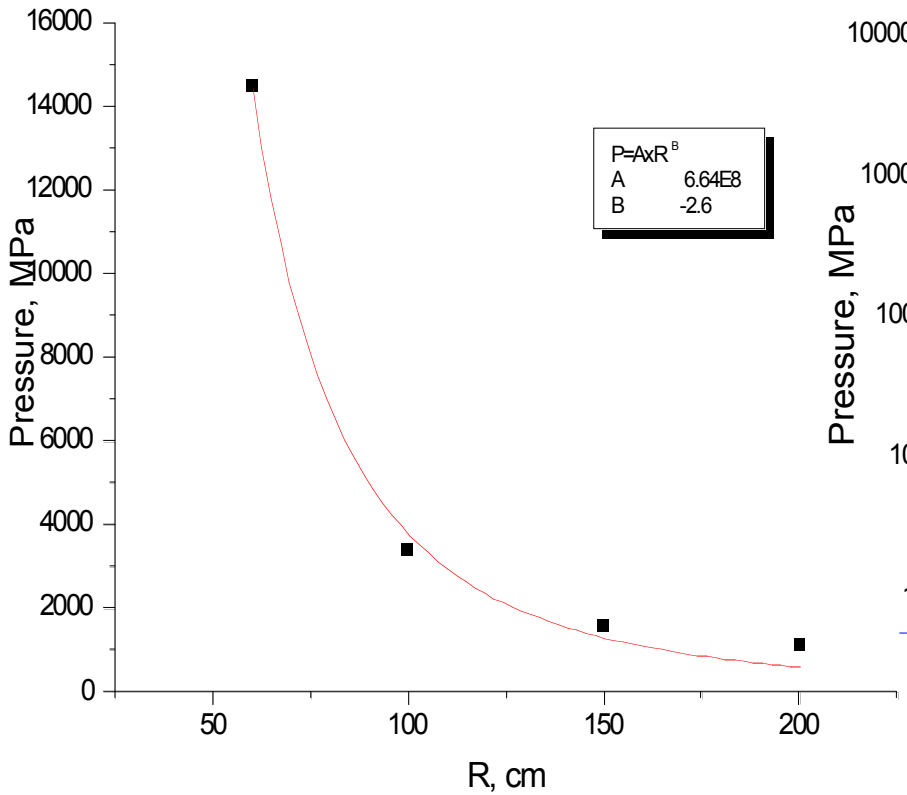
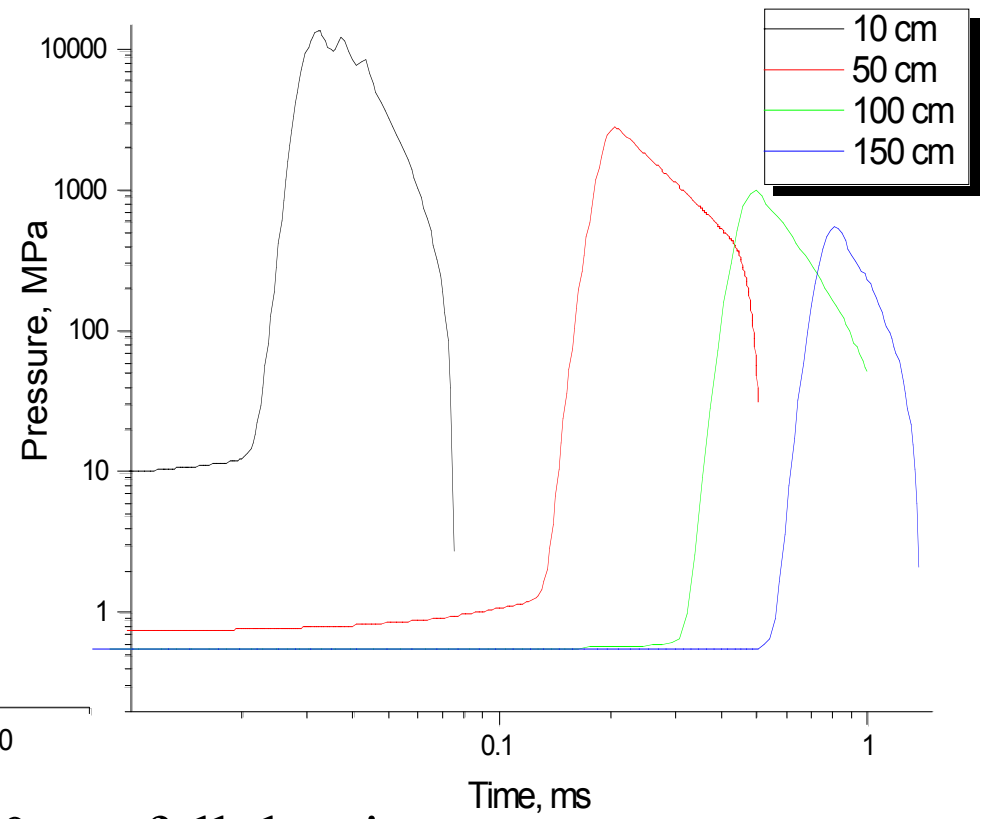
Z-Pinch Power Plant
Pool Pressure Profiles





Li 50-200cm, full density

Maximum pressure at the wall: 550 MPa

Impulse: 0.14652 MPa*s

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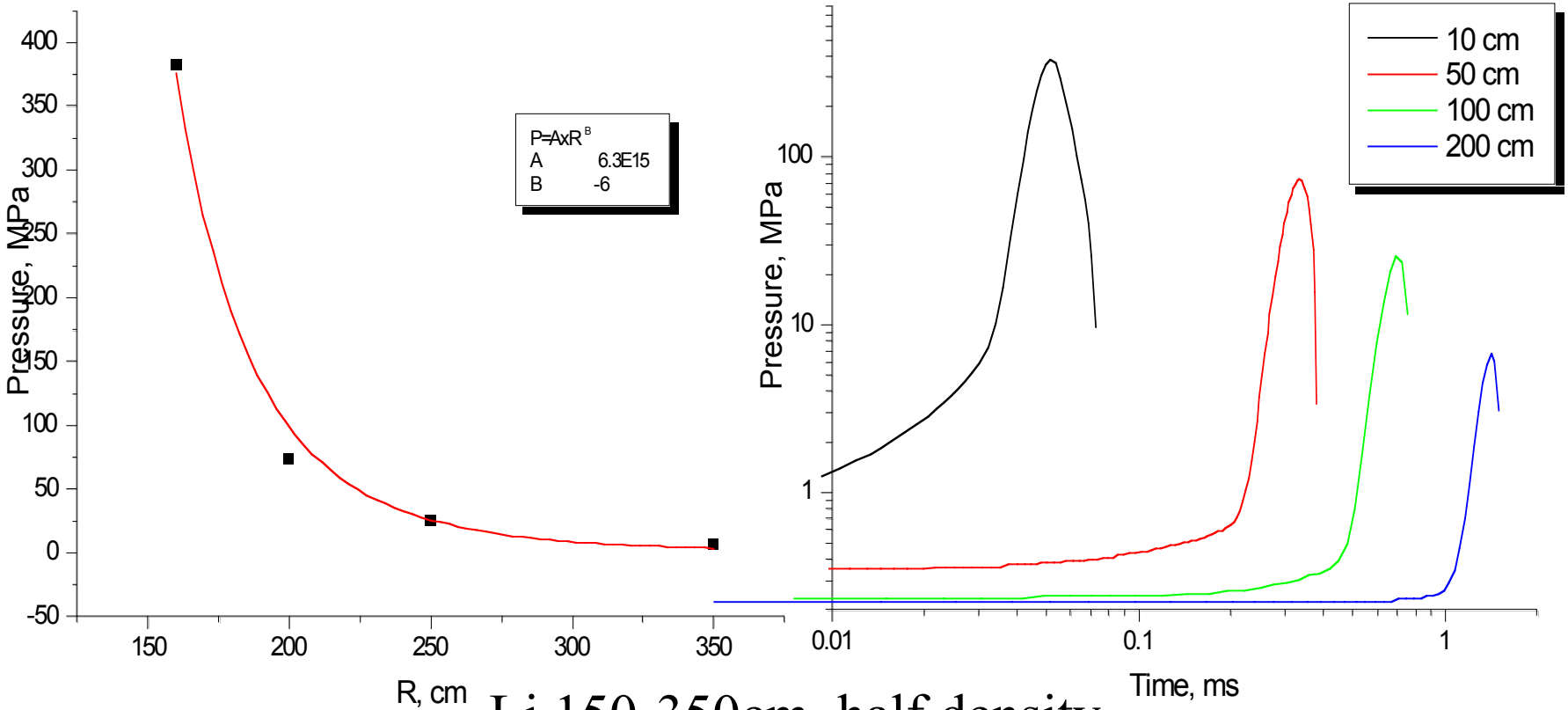
Z-Pinch Power Plant
Side Wall Pressure Profiles



Li 150-350cm, half density

Maximum pressure at the wall: 6.66 MPa

Impulse: 0.00162 MPa*s

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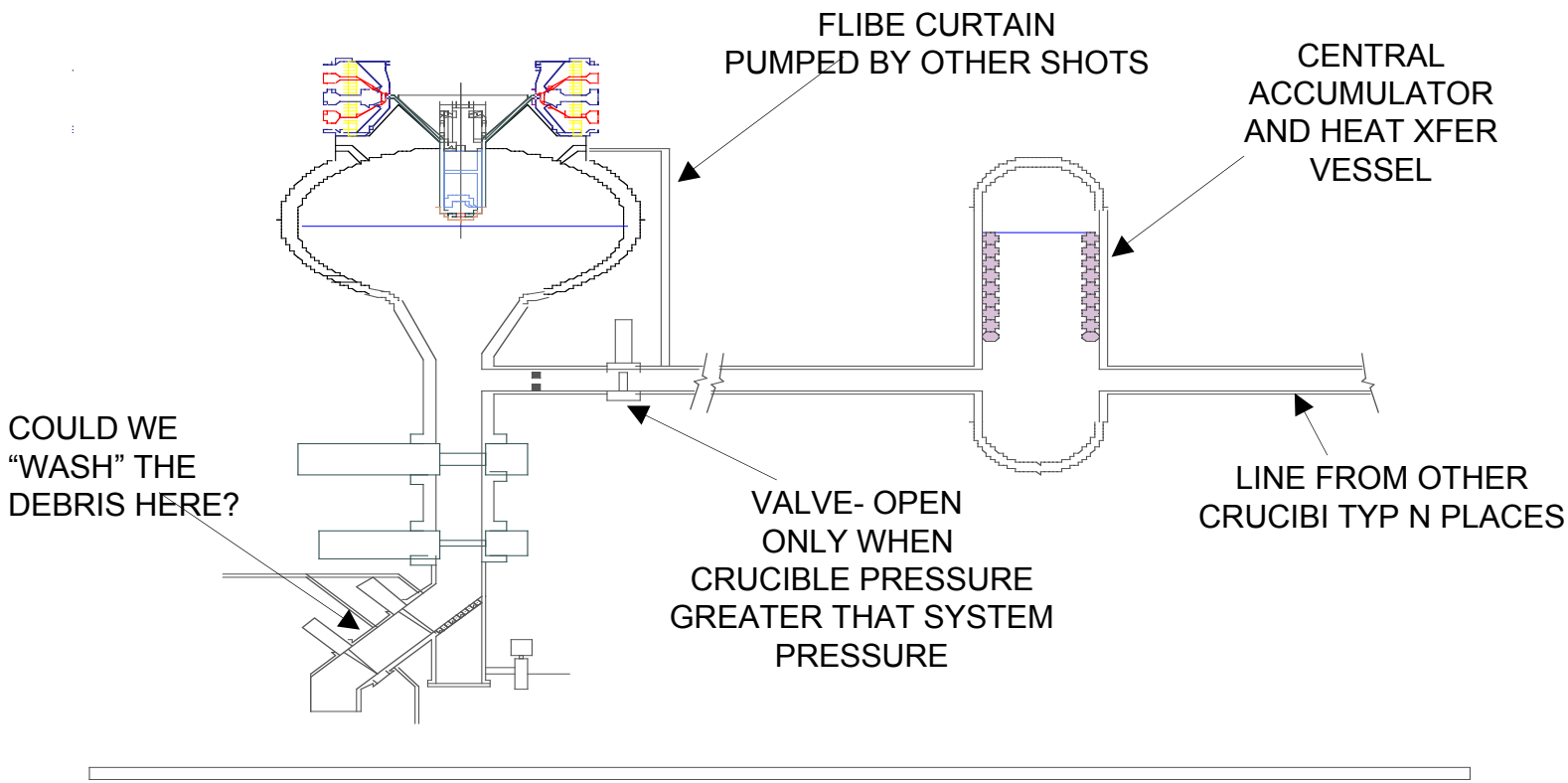
Downward Blast Mitigation



CONCEPT FOR MULTIPLE CRUCIBLE SYSTEM WITH
CENTRAL ACCUMULATOR / HEAT EXCHANGER

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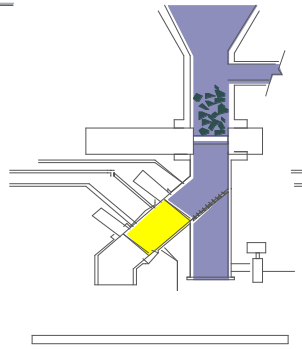
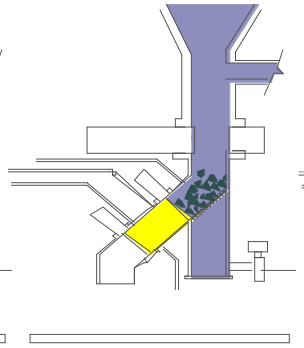
DEBRIS REMOVAL CYCLE CONCEPT WITH SINGLE PRIMARY VALVE

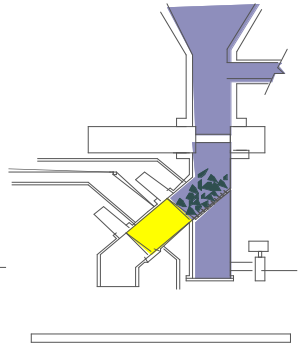
1. AFTER SHOT DEBRIS FALLS TO BOTTOM OF CONE



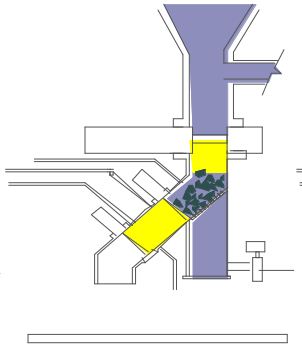
2. PRIMARY VALVE OPENS- DEBRIS INTO SCREEN CHAMBER



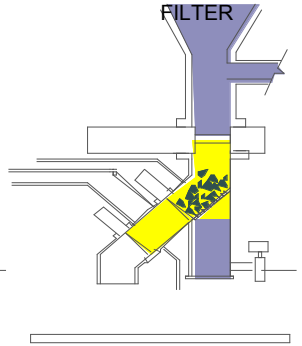
3.PRIMARY VALVE CLOSED



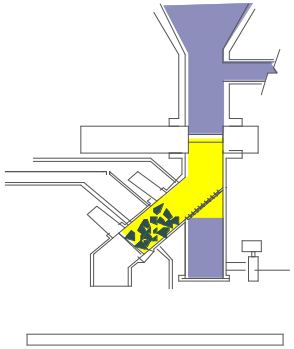
4. HELIUM PUMPED INTO SCREEN CHAMBER



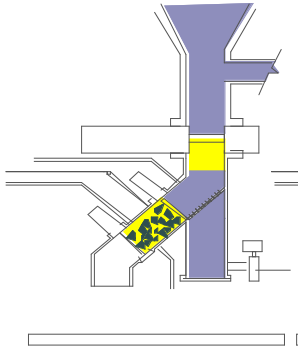
5. SCREEN CHAMBER FILLED WITH HELIUM- DISPLACES FLIBE TO FILTER



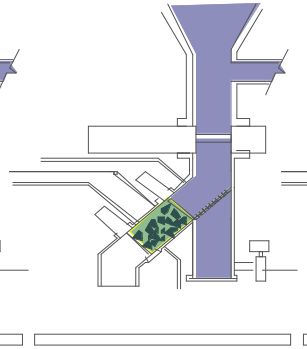
6. UPPER WASH CHAMBER VALVE OPENS- DEBRIS FALLS TO WASH CHAMBER



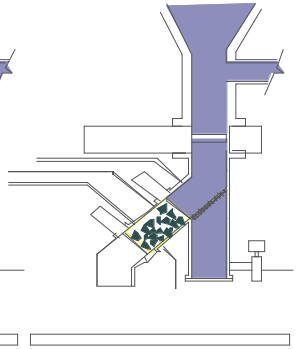
7. SCREEN CHAMBER REFILLED WITH FLIBE



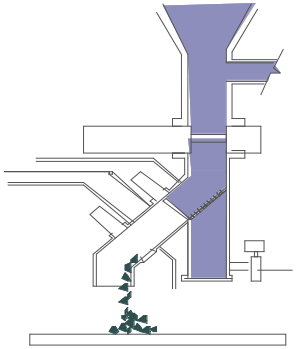
8. HELIUM DISPLACED FROM WASH CHAMBER FLIBE WASHED



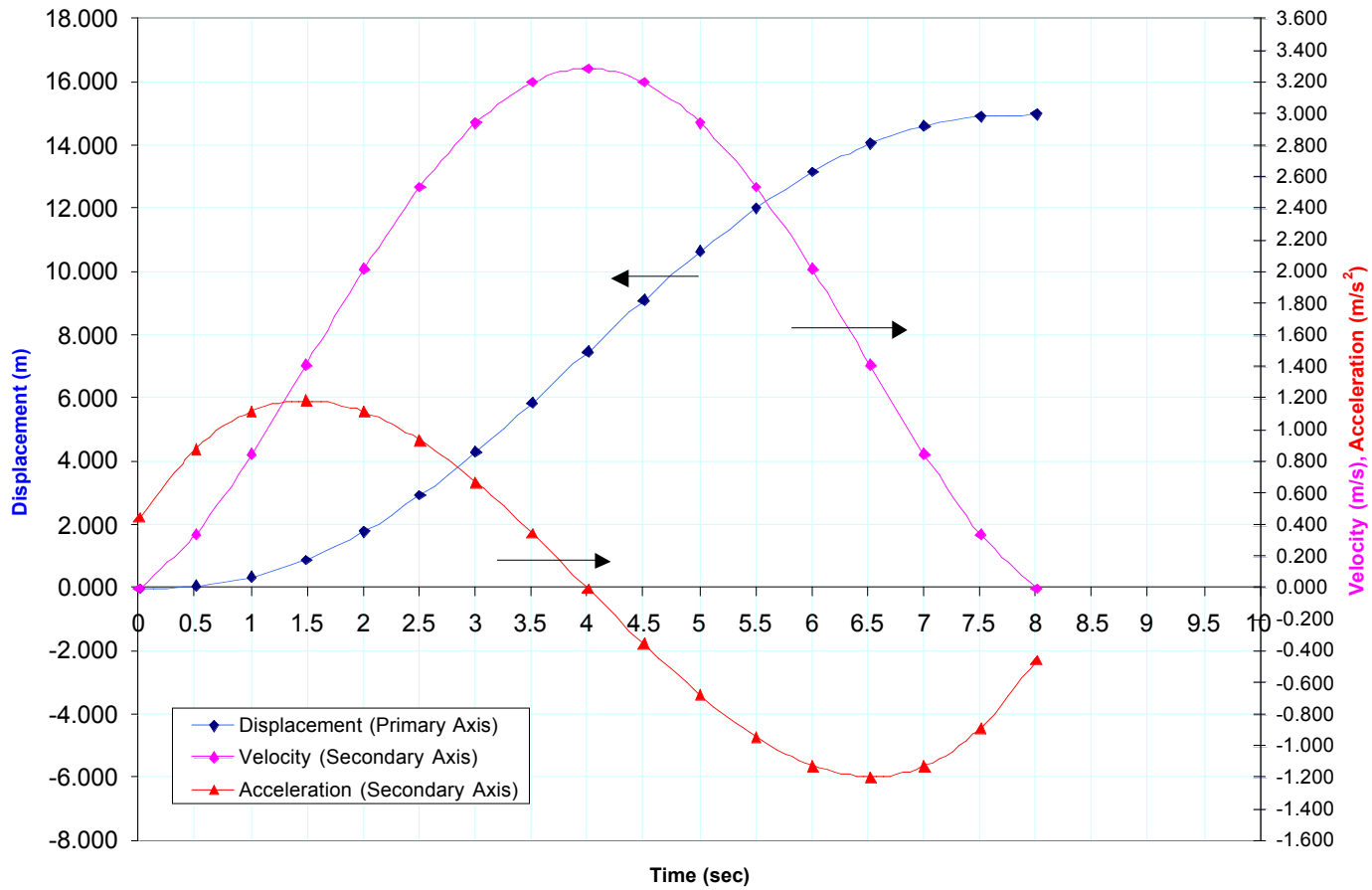
9. WASH CHAMBER FILLED WITH AIR



10. DEBRIS DUMPED ONTO CONVEYER



RTL Acceleration



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Z-Pinch Power Plant
Conclusions

- **A mechanical connection can be made to the pulsed power driver preserving vacuum and protecting vacuum interface of driver.**
- **Repetitive insertion of the Cartridge can easily be achieved on a 10 second time scale.**
- **Containment can be achieved using lithium or Flibe to absorb the neutrons.**
- **Shock can be controlled by using momentum absorbing materials or graded density coolant.**
- **Additional work is needed to control "blow-back" through the RTL and to assure control of debris.**

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