Progress Toward Development of an IFE Power Plant Using Z-Pinch Technology*

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Z- Pinch Approach to ICF
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:
Define a Power Plant Concept utilizing Inertial Fusion Energy driven by a pulsed power z-pinch x-ray source and define a development program.
## Proposed Z-Pinch Power Plant Operating Parameters

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>BASELINE VALUES</th>
<th>RATE CHALLENGE VALUES</th>
<th>YIELD CHALLENGE VALUES</th>
<th>CONVERSION CHALLENGE VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear Energy Released per Pulse (GJ)</td>
<td>3</td>
<td>3</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>Energy Recovery Factor</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>110%</td>
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<tr>
<td>Thermal Energy Recovered per Pulse (GJ)</td>
<td>3</td>
<td>3</td>
<td>20</td>
<td>3.3</td>
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<tr>
<td>Pulse Frequency (Hz)</td>
<td>0.1</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
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<tr>
<td>Thermal Power per Unit (GW)</td>
<td>0.3</td>
<td>0.9</td>
<td>2.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Coolant Temperature (Kelvin)</td>
<td>817</td>
<td>817</td>
<td>817</td>
<td>1550</td>
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<tr>
<td>Thermal Conversion Process</td>
<td>Rankine</td>
<td>Rankine</td>
<td>Rankine</td>
<td>Brayton</td>
</tr>
<tr>
<td>Chamber Pressure (Torr)</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>200</td>
</tr>
<tr>
<td>Thermal Conversion Efficiency</td>
<td>34%</td>
<td>34%</td>
<td>34%</td>
<td>50%</td>
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<tr>
<td>Electrical Output Power per Unit (GW)</td>
<td>0.10</td>
<td>0.3</td>
<td>0.7</td>
<td>0.16</td>
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<tr>
<td>Number of Units per Plant</td>
<td>10</td>
<td>4</td>
<td>2</td>
<td>7</td>
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<tr>
<td>Plant Availability, Capacity Factor</td>
<td>80%</td>
<td>95%</td>
<td>95%</td>
<td>80%</td>
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<tr>
<td>Total Plant Power Output (GW)</td>
<td>1.0</td>
<td>1.2</td>
<td>1.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Annual Power Sales (kWh)</td>
<td>7.1e9</td>
<td>9.9e9</td>
<td>11.3e9</td>
<td>8.1e9</td>
</tr>
</tbody>
</table>
A Z-Pinch Power Plant
Energy Extraction

Brayton Cycle

Rankine Cycle

From CTES
Principal Heat Exchanger
To CTES

Compressor I
Compressor II

Turbine I
Turbine II

Electric Generator

Cooling Fluid

Rankine Cycle
Z-Pinch Plant

From CTES

Principal Heat Exchanger

HP Turbine
LP Turbine
Z-Pinch Power Plant
Conceptual Plant Layout

CONVENTIONAL POWER PLANT
BASED ON SEABROOK
1100 MWe STATION

20 Gigajoules-Fusion @ 0.1 Hz
Z-Pinch Power Plant
Crucible Details

- Replaceable Energy Absorbing Shell
- Pulsed Power Driver
- Inert Gas Flow for Contamination Control
- 10-20 Torr Inert Gas

- RTL
- Tungsten Hemispherical Shell for Energy Reflection
- Wire Array & Fusion Capsule
- Plastic Heat Shield
- Liquid Metal/Molten Salt Pool
- Pool and Debris Momentum Diffuser
- Large Particulate Collections System
- Crucible
- Flibe Pumps
- Flibe Jets
- Cartridge
- Inert Gas Flow for Contamination Control

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A Z-Pinch Power Plant Cartridge Details

- **TUNGSTEN HEMISPHERICAL SHELL FOR ENERGY REFLECTION**
- **REPLACEABLE ENERGY ABSORBING SHELL**
- **Shield**
- **Plunger**
- **Shear**
- **Momentum Trap**
- **Flibe**
- **RTL**
- **Target**
- **Insertion of Wire Array**
- **Insertion of Target Assembly**
- **Vacuum Chamber**
- **Filled and Layered Cryogenic Target Assemblies**
- **Wire Array Assemblies**
Mechanical Testing of A Full-Scale RTL has begun

- Modeled by ANSYS and ABACUS and theory
- Constructed to a mass of 50 Kg
- Manufactured using a spinning process
- 8 constructed for testing of buckling
- 0.6 mm thick by 2 m long and 1 m in diameter
- Designed for 20 Torr differential pressure with 2.5 x below buckling limit
3 MV, 10 MA Driver

10 MV, 0.1 MA Driver
ZP3 Prototype Module Has Been Constructed and Tested

-0.2
0
0.2
0.4
0.6
0.8
1
1.2

0
20
40
60
80
100
120

0 200 400 600 800 1000

rise time = 70ns

1-MA, 100kV, 70ns LTD cavity (top flange removed)
80 Maxwell 31165 caps, 40 switches, ±100 kV
0.1 Ohm load 0.1TW
A Z-Pinch Power Plant
Containment Details

• Flibe has good shielding characteristics
  – Concern for stability at high energy densities
• 0.4 m equivalent thickness of Flibe is needed to make steel crucible wall and driver components last the lifetime of the plant from radiation.
• Larger thickness of 1 m will be used to achieve Tritium Breeding Ratio of 1.1
• Overall energy multiplication is 1.1
• 10% of the energy is deposited in crucible wall
• Containing the shock is a major issue.
Crucible Warm-Up Curve
Preliminary ALEGRA Shock Tube
Metal Foam Experiment Simulation

velocity_z vs. Time for Node 4670

Minimum displz vs. Time

Maximum density_1 vs. Time
Crucible is on the order of a PWR PV
ZP3 Path Forward

• Continue building a broad collaborative effort
• Continue to evolve the Conceptual Baseline
  – Identifying options to minimize development and capital cost
  – Minimize manufacturing requirements
• Refine concepts through modeling and experimentation.
  – Establish benchmarks for codes
  – Identify important scientific research
Status of Research on Z-Pinch Power Plant

• Concept Development
  – Conceptual Baseline in progress
  – Options list under development
• A large collaboration to evaluate the concept
  – identify scientific issues
  – propose research for resolution and technology development
• Working groups have been formed to define issues, set goals, determine costs, and make plans for the six PoP areas:
  – Full development and demonstration of the RTL concept
  – Rep-rated pulse power with an RTL at 1 MA
  – Energy and shock containment
  – Full RTL manufacturing cycle
  – Z-Pinch IFE target development
  – Z-Pinch Power Plant technology