Heat Pipes and Other Heat Transfer Techniques

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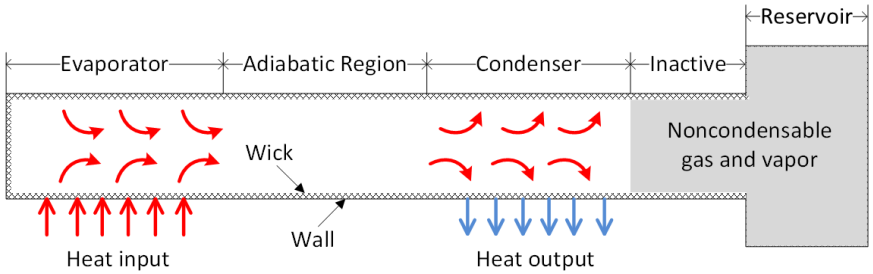
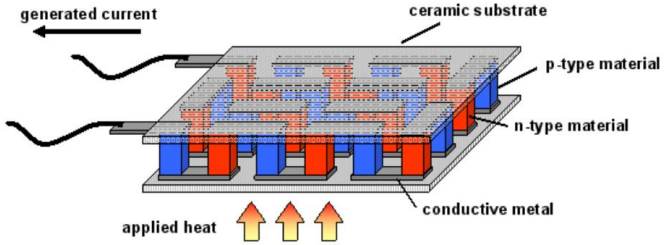
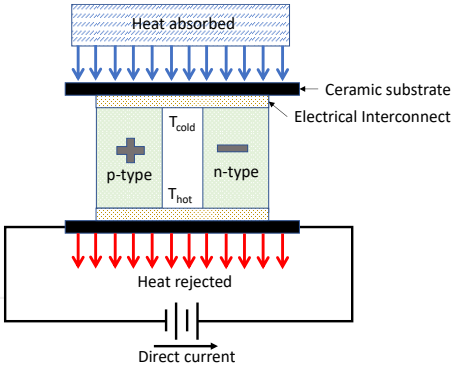
Heat Removal and Thermal Management

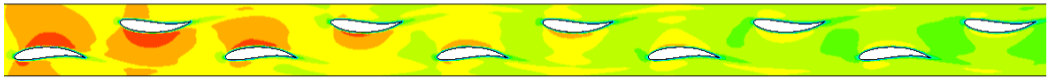
Heat transfer devices

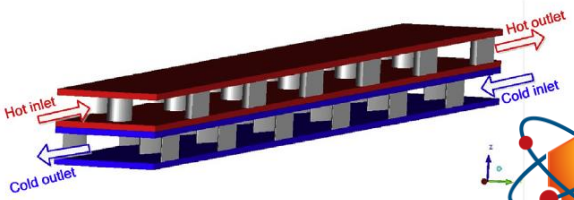
- Constant or variable conductance heat pipes
- Diode heat pipes
- Gas coolant
- Thermosyphons
- Oscillating heat pipes
- Loop heat pipes
- Vapor chambers
- Compact heat exchangers











MRP Microreactor Program

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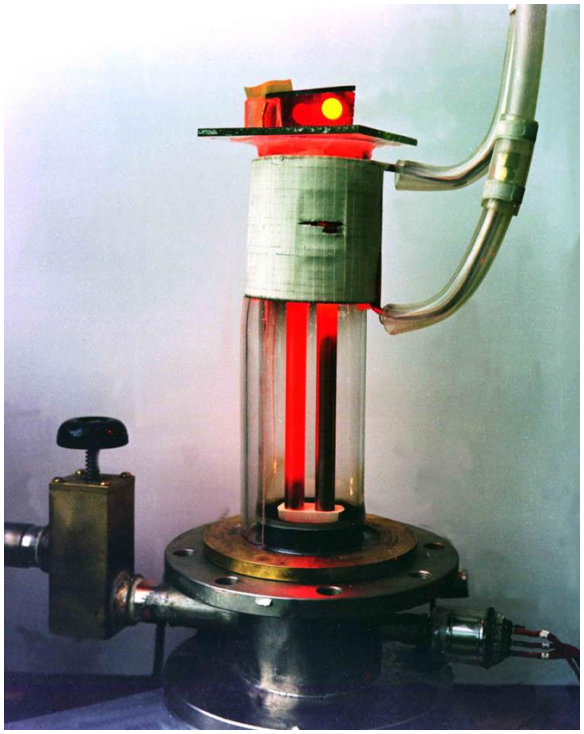
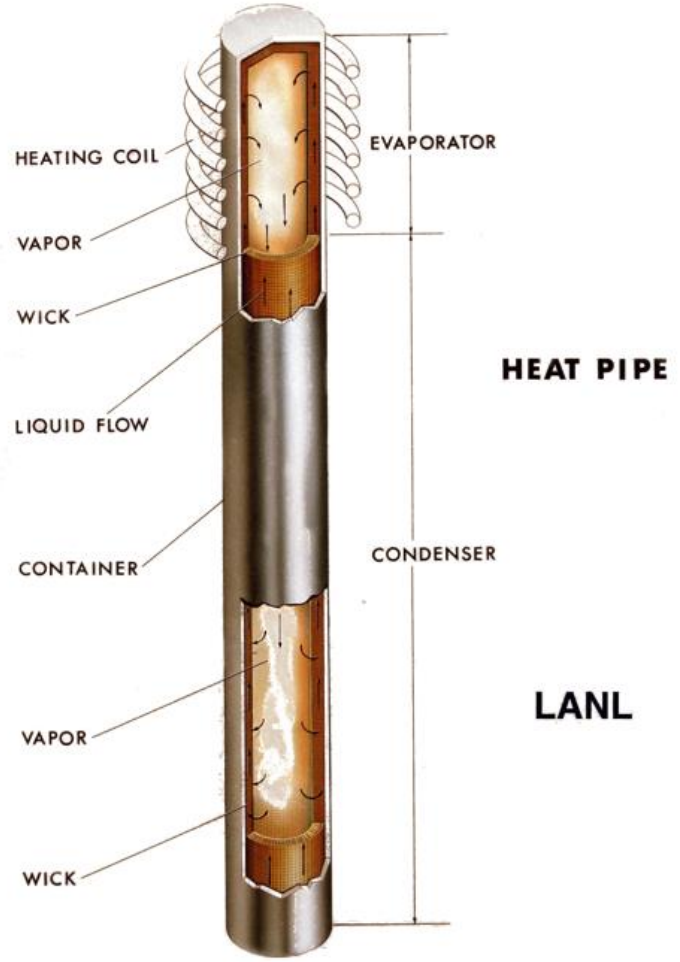
Heat Pipe Basics “Thermal Superconductors”

- Heat pipes transfer heat isothermally by vaporizing a fluid in a hot zone that condense in a cold zone. Fluid then returns to the hot zone via a wick



World’s first alkali metal heat pipe
Los Alamos Scientific Laboratory 1964



Heat pipe operating principle

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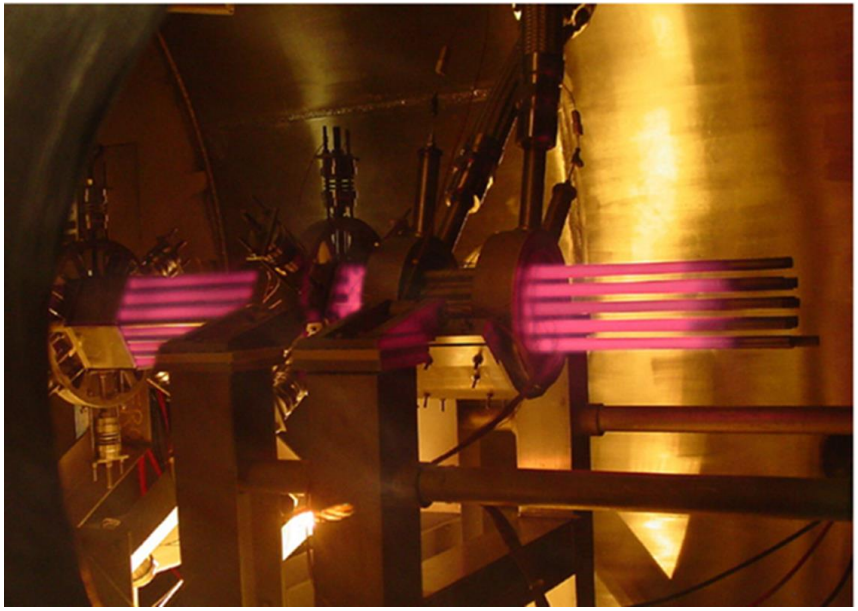
Heat Pipe Cooled Microreactors

- Heat pipes are promising technology for microreactor designs scalable from kilowatt to megawatt thermal power levels

Heat pipes transfer heat with small temperature differences. No moving parts.

Benefits Relevant to Microreactor Operation

- **Passive heat removal (self-pumping)**
- **No single point failure**
- **Generic interface to multiple heat sinks**
- **Established reliability**
- **Modular design allowing testing before installation**
- **Realistic life testing on a prototype level**



Heat Pipe Reactor Electrically Heated Demonstration (700°C) LANL/NASA 2005

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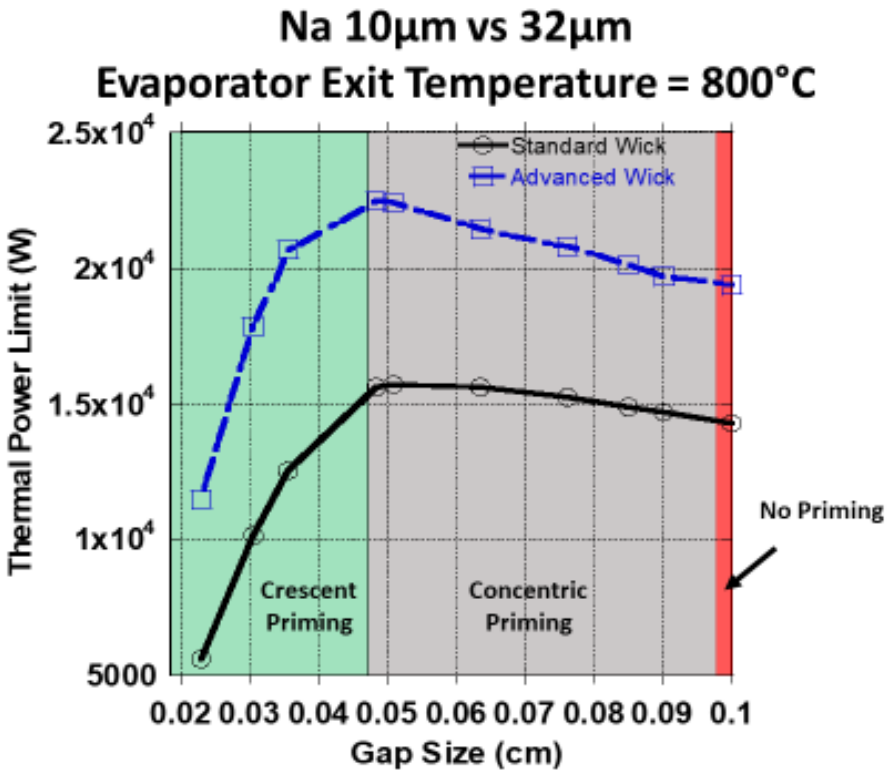
Advanced Heat Rejection Studies

- Apply heat pipe technology to moderator thermal management to keep hydrogen dissociation loss under 10% over 5 year life of reference reactor design.
- Produce advanced wick designs to NQA-1 quality standards and to reduce effective pore radius in manufactured annular wicks from 32 µm to under 11 µm (eWick37)
- Generate techniques to characterize probability distributions for individual heat pipe limits for use in cascade failure analysis.



Los Alamos Advanced Wick Designs

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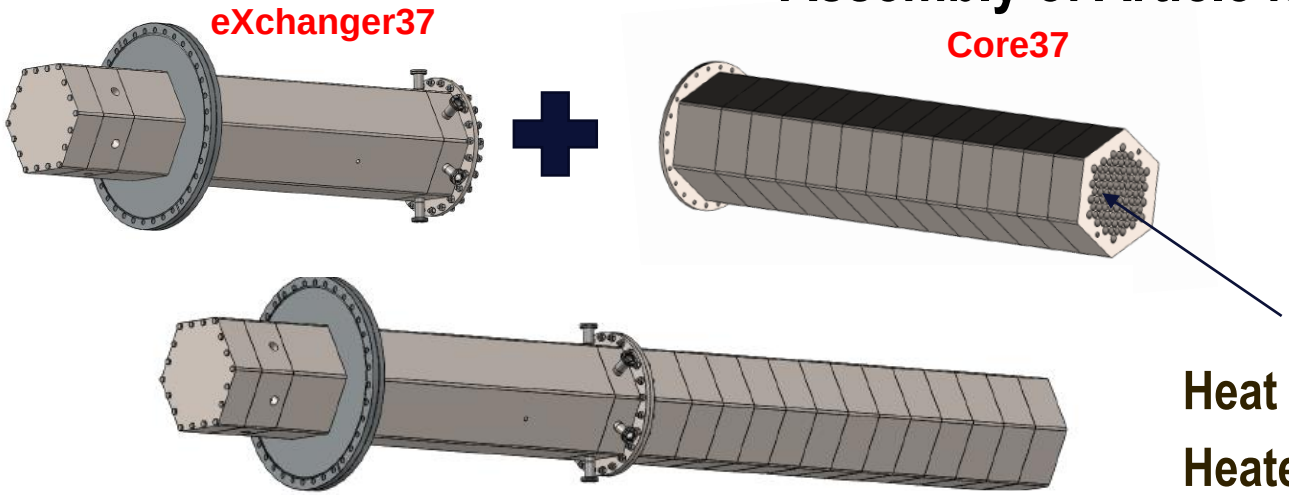
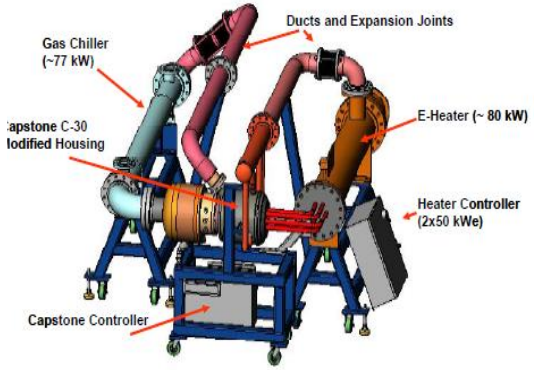
Heat Pipe-to-Heat Exchanger Interface

To Be Tested at MAGNET Nonnuclear Test Bed

Assembly of Article is Underway



Heat Pipes/ Heaters



Modified Capstone C30 Power Conversion Unit

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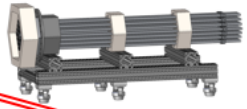
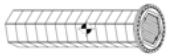
Integrated Heat Pipe Core & Heat Exchanger Fabrication Demonstration & Test Article

gCart37

Handling Cart

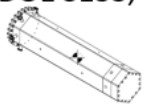


Core37
US DOE S133,464



Monolithic
Reactor Core
Block

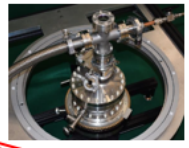
eXchanger37
US DOE S133,464



Monolithic
Heat Pipe to
Gas Heat Exchanger

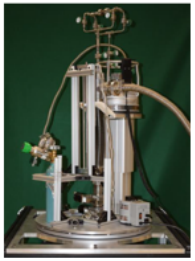
eWick37 (NQA-1)
US DOE S133,680

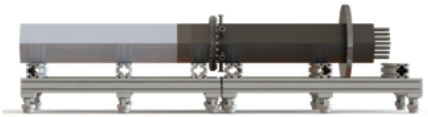
Mass Produced
NQA-1 Quality
High Capacity
Heat Pipe Wicks

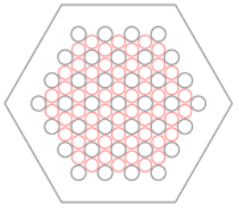


eFill37
US DOE S133,662

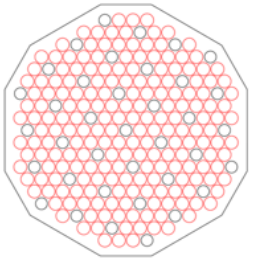
Mass Produced
High Purity
Heat Pipe Fill
And Seal







Thermal Hydraulic
Similarity



Nuclear Similarity
(criticality)

Los Alamos
NATIONAL LABORATORY
EST.1943

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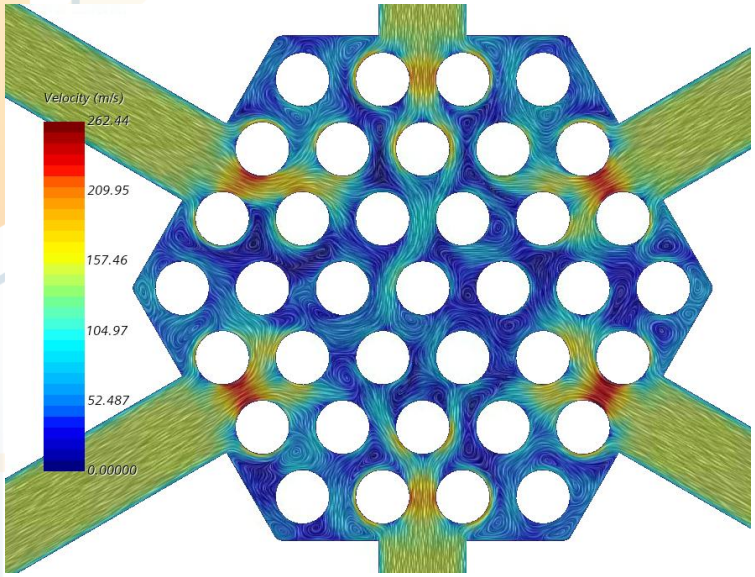
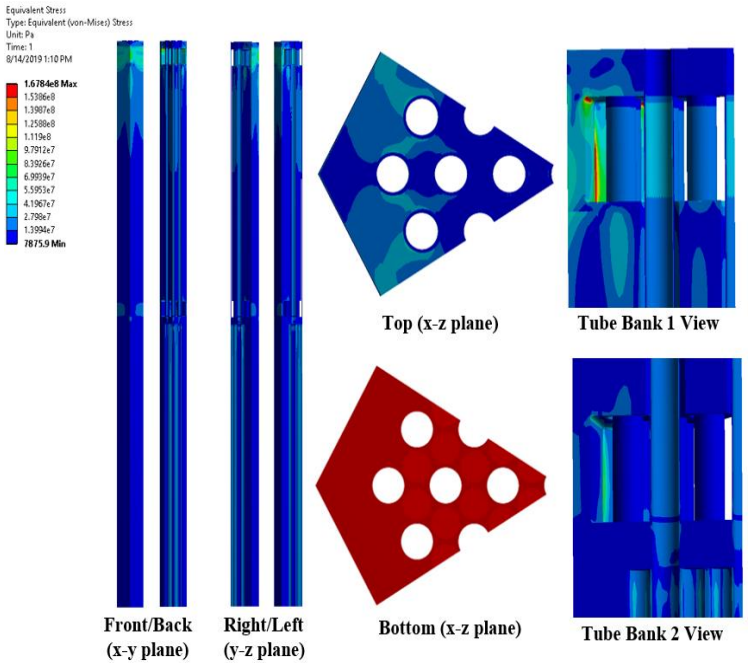
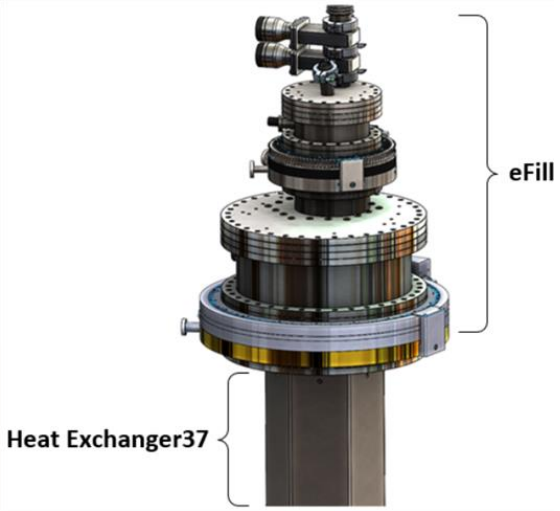
Test Article Analysis and Fabrication



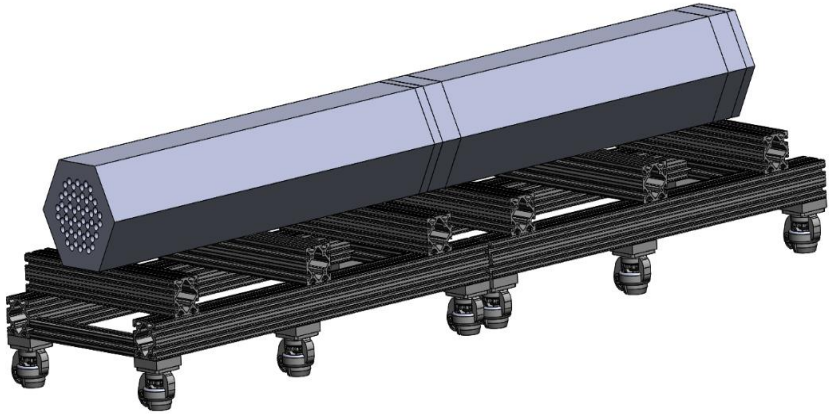
CFD Analysis of Test Article Heat Exchanger



Finite Element Structural Analysis of Monolithic Core and Heat Exchanger



eFill37 Heat Pipe Processing Unit

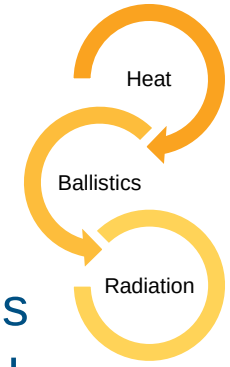


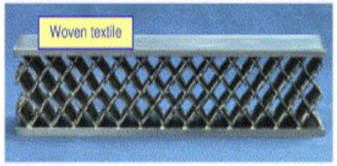
Test Article on Handling Cart

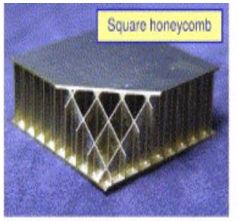
MRP Microreactor Program

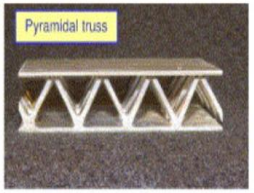
Protective Materials

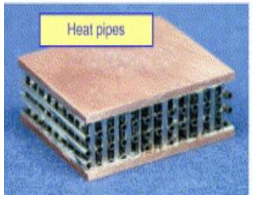
- Additive manufacturing supports modular manufacturing and unconventional geometries
  - Ideal for prototype fabrication for advanced heat transport concepts applicable to generic microreactor designs
  - Research novel ways of incorporating thermal management devices into structures
  - Manufacturing process development from microstructures to components
  - Thermal transport in extreme environments (radiation, high temperature, thermal cycling, etc.)
  - Applications include printed thermal heat spreaders, insulators, radiation shields for PCU and external equipment











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Conclusions

- Various mechanisms are possible for heat transfer from microreactors including gas coolant, heat pipes, pumped single phase liquid metal loops
- Heat pipes have formed the basis of a number of space/small reactor designs over the past 50 years.
- Heat pipe use in commercial nuclear power has lower technology readiness levels than gas coolant; thus it was focus of heat transfer work in MRP.
- Advanced heat pipe wicks will increase efficiency of thermal energy production.
- First-of-a-kind non-nuclear test is planned with 37 heat pipes in an integrated array to understand operation in microreactor-like environment.

MRP Microreactor Program

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