Microreactor AGile Non-nuclear Experimental Test bed / Helium Component Test Facility (MAGNET / He-CTF)

T.J. Morton

MRP Microreactor Program

Functional Requirements

- Provide a general-purpose, non-nuclear test bed for prototype microreactor design evaluation
- Collect thermal-hydraulic performance data for prototypical geometries and operating conditions
  - Test article and flow loop temperature, pressure, and flow data for steady state and transient operations
  - Displacement and temperature data for design performance verification and accompanying analytical model validation (V&V)
- Enhance the technical readiness level of novel microreactor components, e.g., heat pipes or other passive heat removal technologies
- Identify, develop, and test advanced sensors for potential autonomous operation
- Evaluate interfaces between simulated microreactor components
- Demonstrate the application of advanced techniques, e.g., additive manufacturing and diffusion bonding, for microreactor applications
- Address knowledge gaps to support high-temperature reactor components and systems

Design Bases

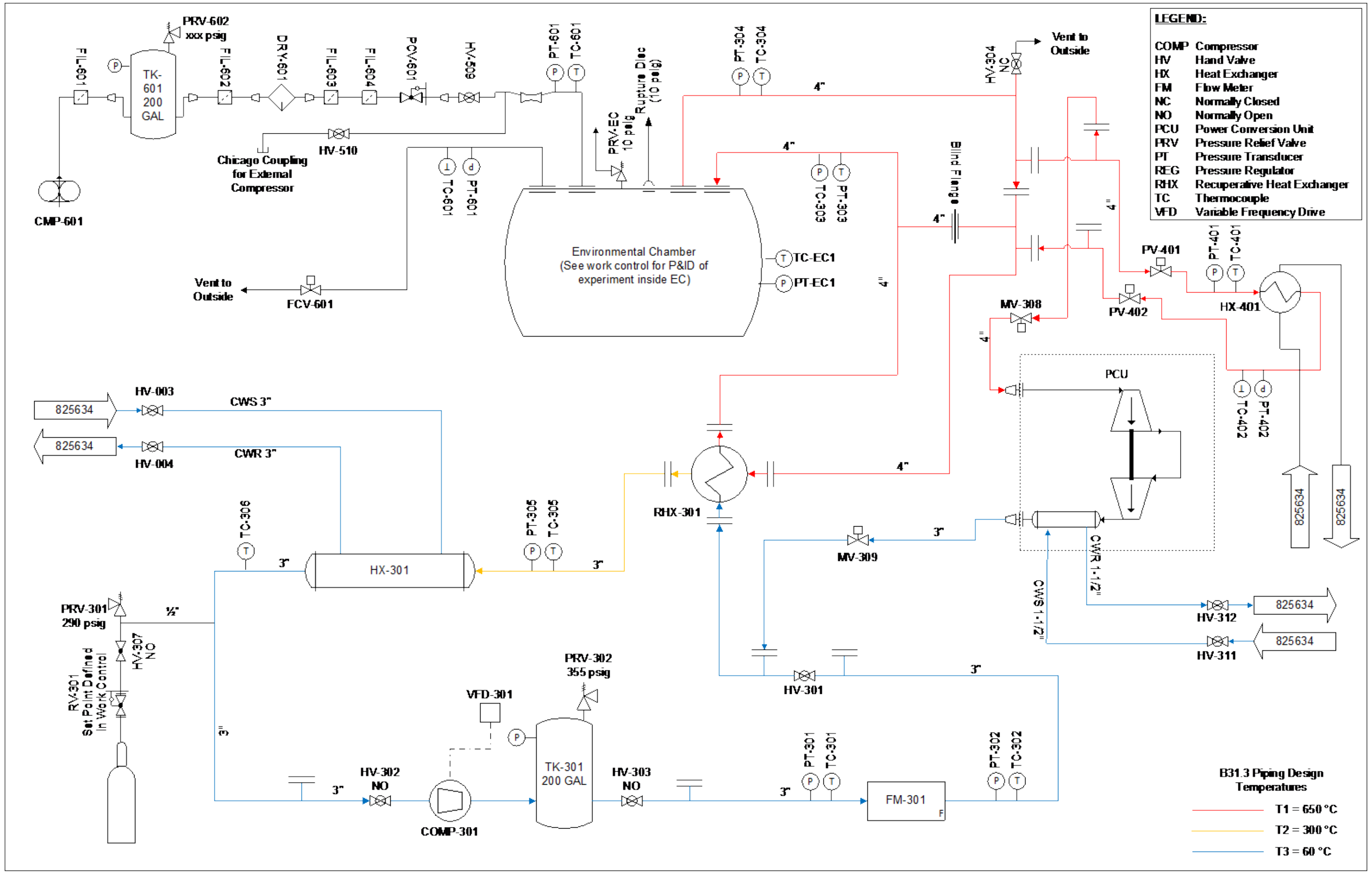
Typical Test Article Operating Parameters

- 600°C T_{OUT}
- 360°C T_{IN}
- 250 kW heat input
- 1.2 MPa
- 350°C air at 3 bar for shell side heat removal

General Design Bases

- Test article ≤ 750°C
- Piping designed to ASME B31.3 "Power Piping"
- Gases – He, N_2, compressed air
- 2.0 MPa maximum operating pressure
- Flexibility to integrate other systems or install additional compressor
- 2 x 80 kW process heaters

Flow Diagram



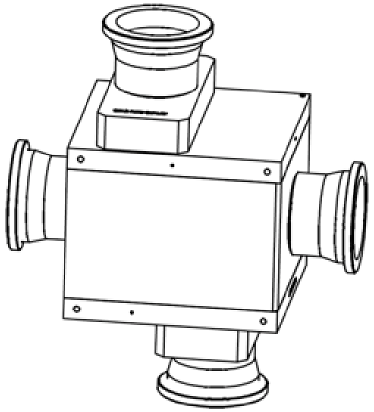
MAGNET / He-CTF Process Flow Diagram

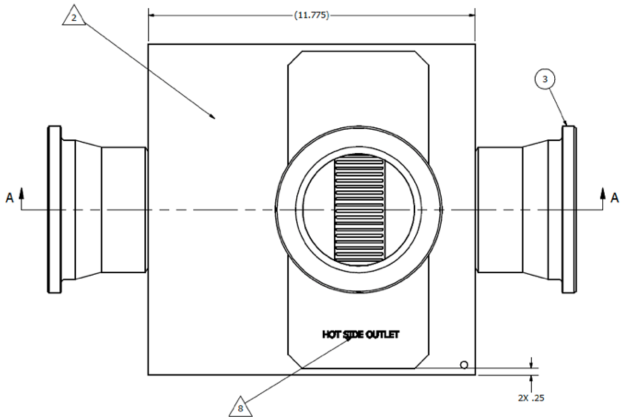
Recuperative Heat Exchanger (RHX-01)

RHX-01 (Recuperator)	
Parameter	Value
Gas	Compressed N_2
Mass Flow Rate (kg/s)	0.938
Design Pressure (bar_g)	22
Design Temperature (°C)	650
Cold Side	
Nominal Inlet Pressure (bar_g)	12
Nominal dP (bar)	0.375
T_{COLDin} (°C)	38
$T_{COLDout}$ (°C)	360
Hot Side	
Nominal Inlet Pressure (bar_g)	10.625
Nominal dP (bar)	0.375
T_{HOTin} (°C)	600
T_{HOTout} (°C)	Heat balance

Advanced, diffusion bonded, compact platelet HX well suited to the application

- small flow channels
- custom designed and fabricated





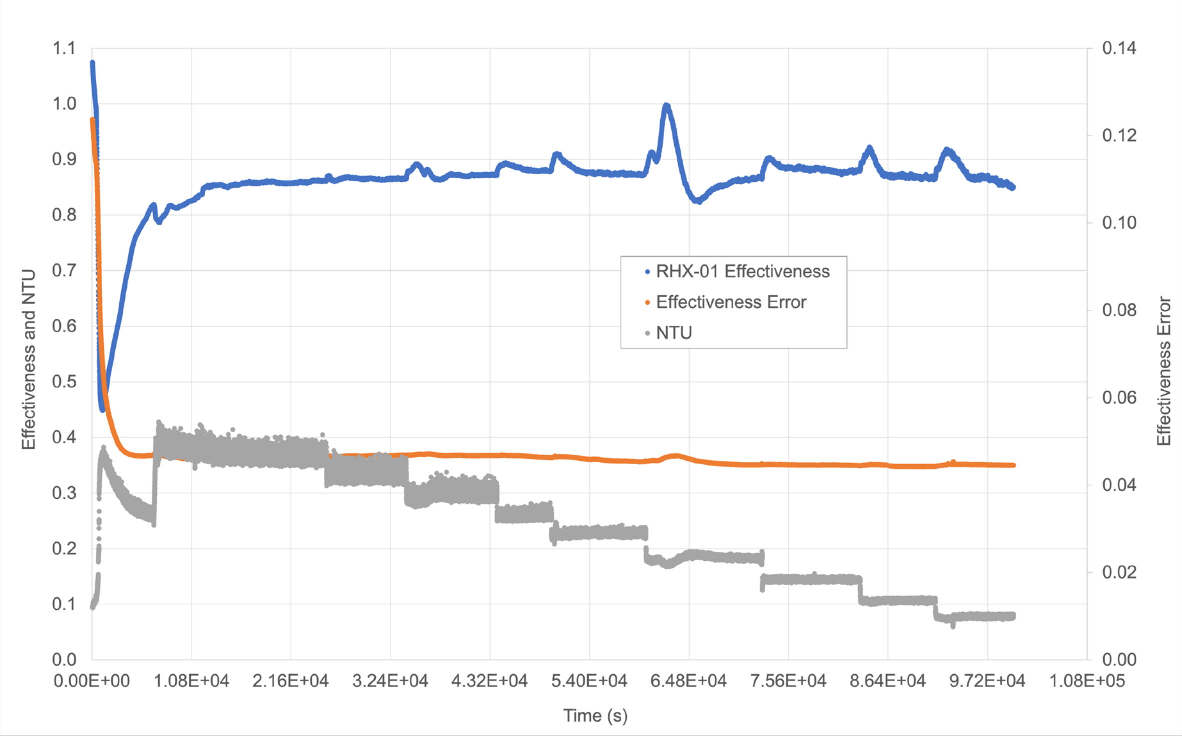
Proprietary He-to-Air HX Testing

- He-CTF construction funded by NRIC
- Proprietary data – no public sharing of analysis
- Analyzed effectiveness (ϵ) of RHX-01 instead

$$\epsilon = \frac{q}{q_{max}}$$

  - Ideal gas (He)
  - Specific heat capacity ratio = 1
  - Mass is conserved (closed loop)

$$\epsilon = \frac{T_{CO} - T_{CI}}{T_{HI} - T_{CI}}$$



RHX-01 Effectiveness

- Calculate NTU

$$NTU = \frac{UA}{c_{min}}$$

$$\dot{Q} = UA\Delta T_{LM}$$

$$\Delta T_{LM} = \frac{\Delta T_H - \Delta T_C}{\ln\left(\frac{\Delta T_H}{\Delta T_C}\right)}$$

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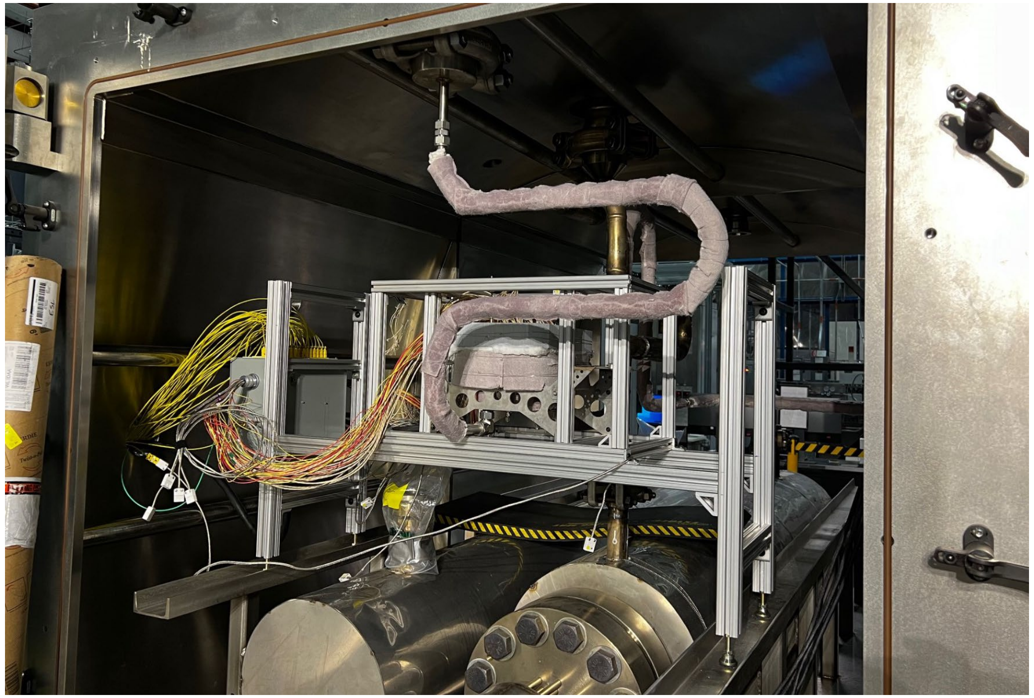
Advanced Heat Pipe Interface Heat Exchanger (HPIHX) NEUP with University of Wisconsin

- NEUP 21-24226 “Cost Reduction of Advanced Integration Heat Exchanger Technology for Micro-Reactors”
- Task 6 – Test Prototype HPIHX at MAGNET
  - ~30 hours of testing
  - Temperatures up to 650°C
  - Pressures up to 600 kPa
  - N_2 flow rates up to 0.1 kg/s
- Phase II proposal submitted to continue this work



Installed HPIHX

Facility/System Improvements

- Thermal integration of MAGNET and Thermal Energy Distribution System (TEDS)
- Replace access scaffolding with permanent mezzanine
- Replace controls
- Integrate Brayton-cycle power conversion unit (PCU)

New Controls Cabinet with Opto22 Hardware

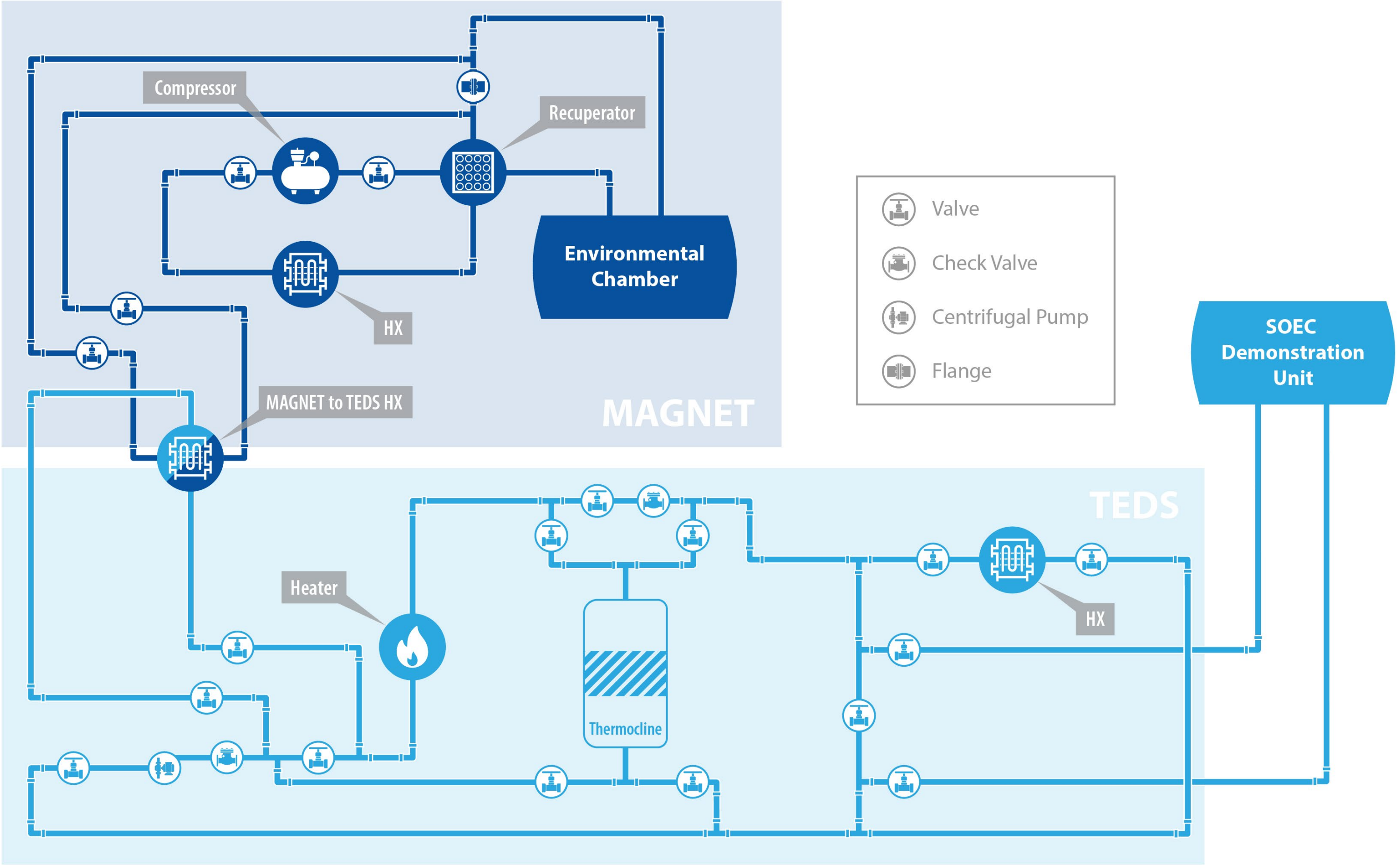
MAGNET-TEDS HX

- Thermal integration of MAGNET and TEDS for integrated energy systems demonstration and modeling validation
- Funded by Cross-cutting Technology Development Integrated Energy Systems (CTD-IES) program

HX Selection Inputs

Gas Side		Oil Side	
Fluid	N_2	Fluid	Therminol®66
Design Pressure	22 bar	Design Pressure	10.3 bar (150 psi)
Nominal Operating Pressure	20 bar	Nominal Operating Pressure	1 bar (14.5 psi)
Design Temperature	650°C	Design Temperature	375°C
Nominal Inlet Temperature	600°C	Nominal Inlet Temperature	325°C
Nominal Outlet Temperature	Heat Balance (calculated)	Nominal Outlet Temperature	225°C
Flow Rate	0.938 kg/s	Flow Rate	14 gpm

Dynamic Energy Transport And Integration Laboratory (DETAIL)



DETAIL Diagram

MAGNET-TEDS HX

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Access Mezzanine

- Access to elevated instrumentation required temporary scaffolding with additional training, qualification, and maintenance requirements
- A permanent mezzanine increases safety and lowers annual maintenance and training expense

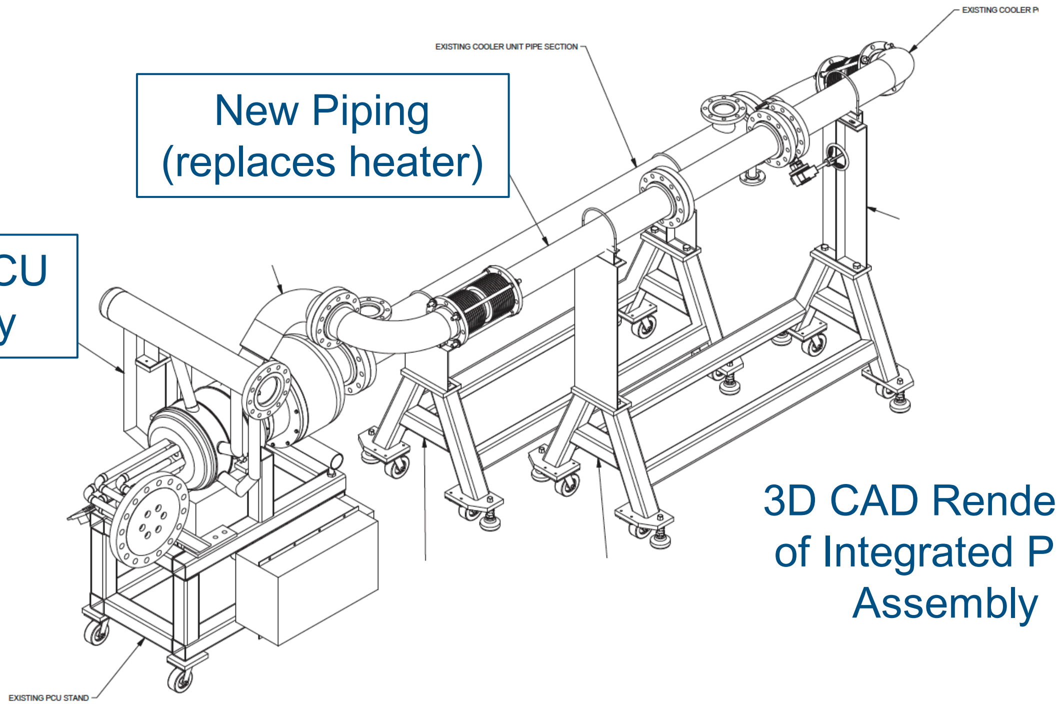
Access Mezzanine

Controls

- Replaced National Instruments^{TM} PXi hardware and LabView SCADA with Opto22 groov EPIC industrial controllers and Inductive Automation's Ignition SCADA
- I/O cards and devices more flexible in terms of types of inputs and outputs supported
- Easier integration with commercial PLC and external controls (e.g., digital twin)

Power Conversion Unit (PCU)

- Piping, structural, and electrical construction designs complete
- Requests for proposal sent to construction contractors
- Construction estimated to begin April 1 and complete by August 30
- Controls integration in September and shakedown testing in FY25



New Piping
(replaces heater)

Existing PCU
Assembly

3D CAD Rendering
of Integrated PCU
Assembly

Conclusion

- Collaboration with industry and research partners demonstrated by successful testing in MAGNET / He-CTF

- Upgrades provide long-term cost savings and operational flexibility for demonstration support

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