Solid Oxide Fuel Cell/Gas Turbine System Cyberphysical Simulation for High Electrical Efficiency Cogeneration

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Presentation Contents

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Introduction of Scope and Team Members

*Build upon the National Energy Technology Laboratory's high electrical efficiency, Brayton cycle-style, recuperative solid oxide fuel cell/gas turbine cyberphysical system

*Develop a high electrical and cogeneration efficiency combined heat and (hybrid) power system that exhibits dynamic robustness through the operation of a high-temperature bypass valve across the hot side of the recuperator

*Ideal for efficient, dynamic, on-site power and heat production at high power-to-heat ratio manufacturing facilities

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*Conduct system-level simulations and analyses across variable power, heat loads and bypass valve settings

*Determine their effects on heat supply, electrical efficiency, and cogeneration efficiency

The University of Texas at El Paso:

*Physically design, develop, and characterize the recuperator bypass valve

National Energy Technology Laboratory:

*Provide a baseline for system simulation

*Provide simulation capabilities and access to a cyberphysical system to test bypass valve within realistic flow conditions

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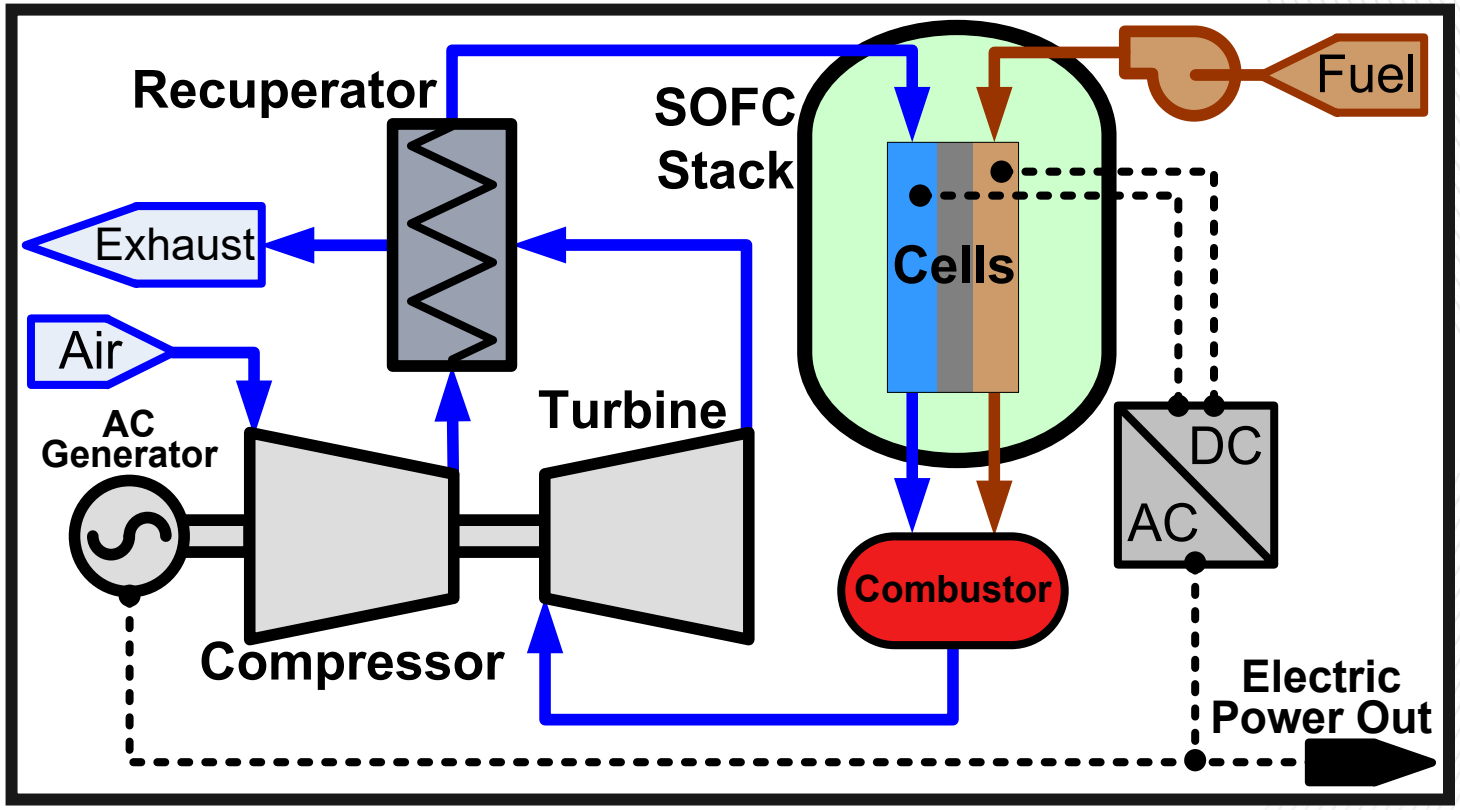
Solid Oxide Fuel Cell/Gas Turbine (SOFC/GT) Systems

- Compressed air increases fuel cell voltage and is required for turbine expansion to atmosphere
- Fuel cells efficiently and directly convert fuel energy into DC electricity by allowing the air to electro-oxidize fuel
- Solid oxide fuel cells can utilize a variety of fuels and can better tolerate impurities
- Electrochemical reactions also act as a heat source to the cycle and combustor burns any residual fuel to further heat air
- Turbine and generator convert thermal energy of compressed, hot air into AC electricity
- Recuperator reclaims thermal energy that is not converted to power by the turbine and generator
- Hybrid fuel cell and turbine power allow system to achieve high electrical efficiencies



Generic System Schematic

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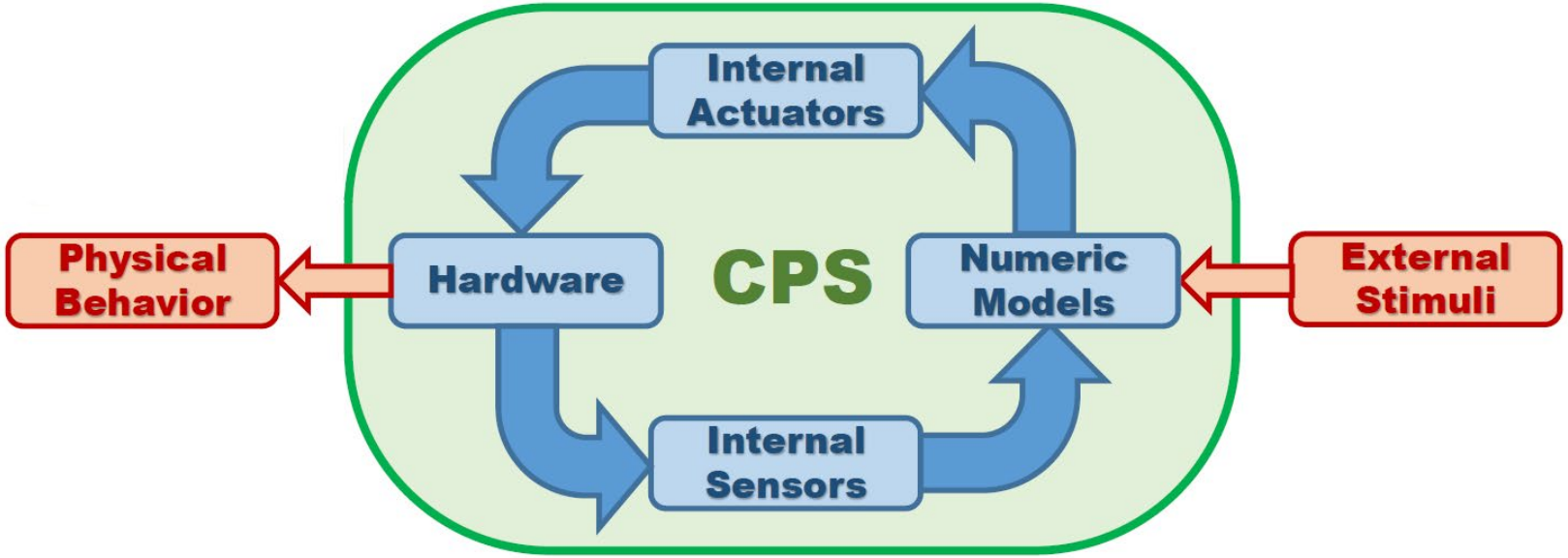
Cyberphysical Systems and NETL's HyPer

Cyberphysical systems combine physical components with virtual simulations to create a cost-effective means of testing a system's behavior

This is accomplished by using external stimuli from real, physical components as inputs to numerical models of virtual components that operate actuators and hardware within the physical side of the system to mimic the behavior of real versions of virtually simulated components

HyPer is the National Energy Technology Laboratory's solid oxide fuel cell/gas turbine cyberphysical system that contains a real compressor, turbine, generator, and recuperator and a virtual solid oxide fuel cell stack that is simulated with a storage tank and combustor



Cyberphysical System Flow Diagram

HyPer Cyberphysical System

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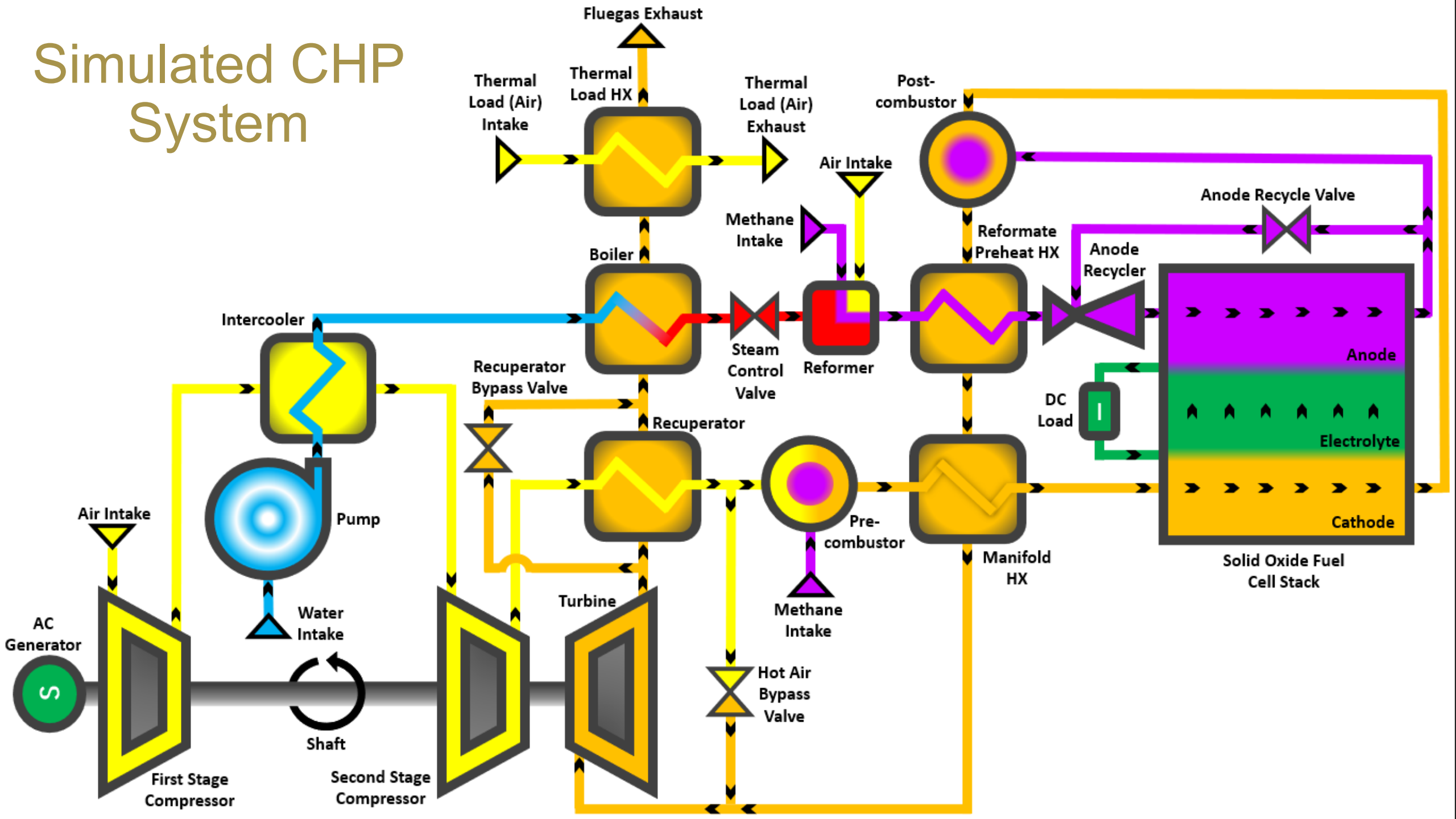
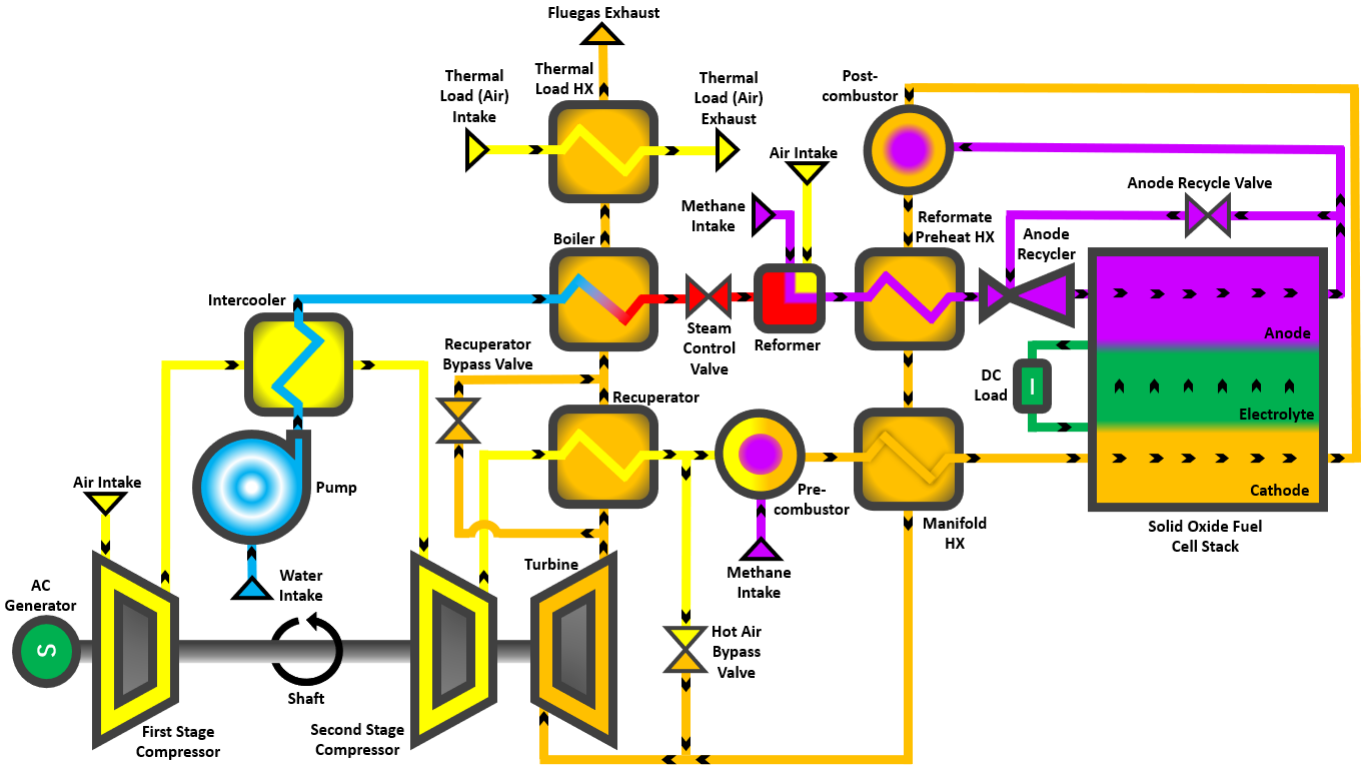
Simulated CHP System



Research Methods:

System-Level Simulations and Analyses:

- Reference/Atmospheric Conditions: 25 C, 1 atm
- Compressor Pressure Ratio: 4
- Number of Fuel Cells: 1000 Cells
- Anode Recycle: 40%
- Reformer Temperature: 526.85 C (800 K)
- Fuel cells, post-combustor, and reformer are simulated in MATLAB and Simulink, all other components are simulated in Ebsilon
- System is operated throughout a range of powers (100 kW + 10 kW steps) and percentages of working fluid bypassing the hot side of the recuperator (0% + 10% or 5% steps)
- Fuel cell current and working air mass flow rate are simultaneously changed to meet total power and fuel cell percentage of total power (~ 65% of total power)
- Fuel mass flow rate to the reformer is changed to meet set fuel utilization
- Fuel mass flow rate to the pre-combustor is changed to meet average cell temperature (~ 835 C), and therefore increases as the amount of air bypassing the recuperator increases
- Thermal load mass flow rate (air on cold side of thermal load heat exchanger incoming at 25 C) is increased until flue gas on hot side of thermal load heat exchanger decreases to 100 C or becomes the minimum heat capacity fluid by 15%

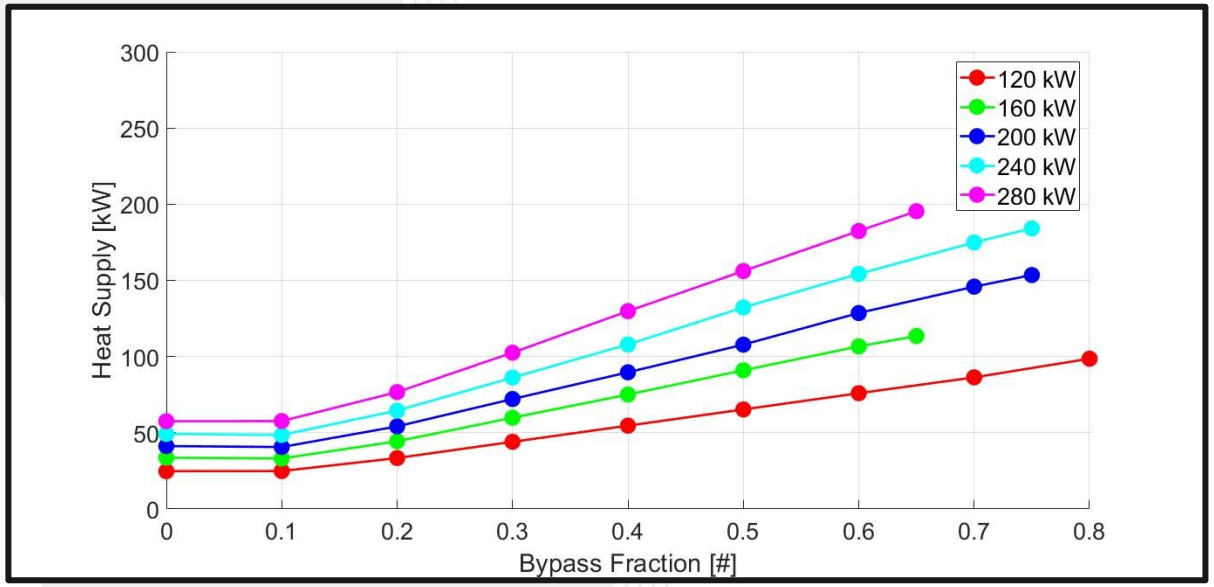


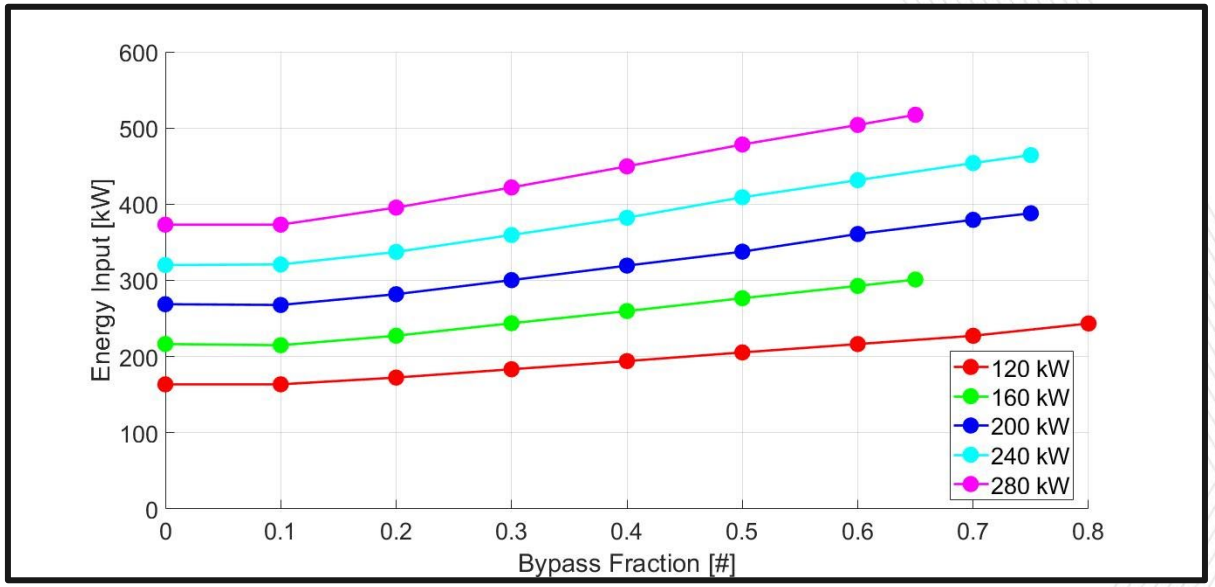
Recuperator Bypass Valve:

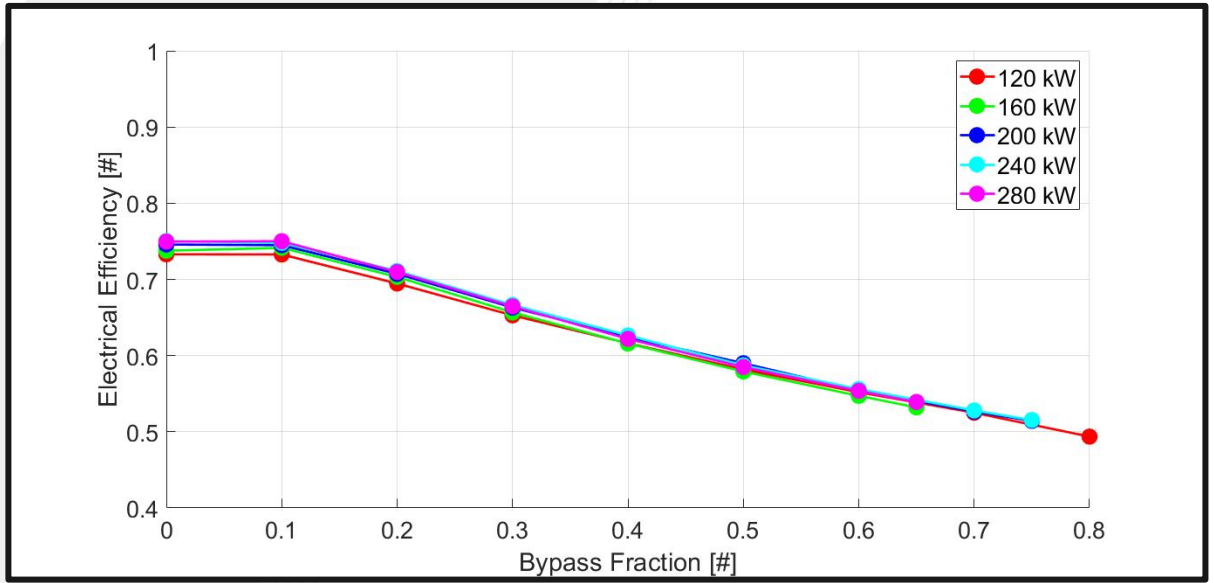
- Valve is designed in CAD and is initially tested under low temperature and low mass flow rate conditions at the University of Texas at El Paso
- Valve to be inserted into NETL's HyPer to be operated and tested under more realistic temperatures, pressures, and mass flow rates

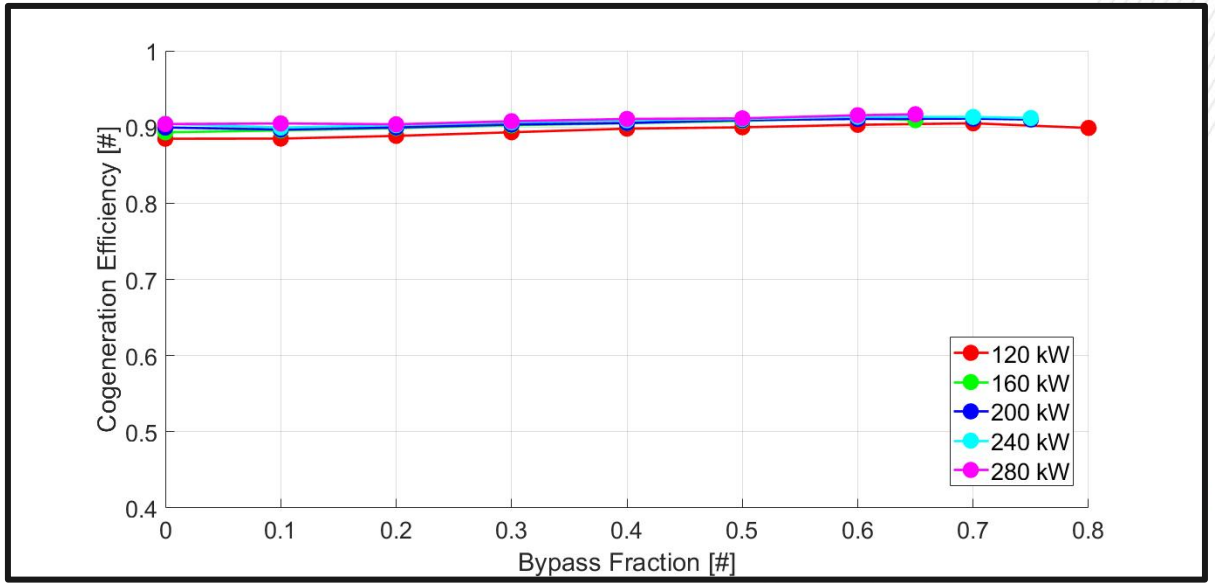
Preliminary Simulation Results: Overall Parameters

All x-Axes: Fraction of Fluid Bypassing Hot Side of Recuperator through Bypass Valve - All Legends: Total Power Supply of System



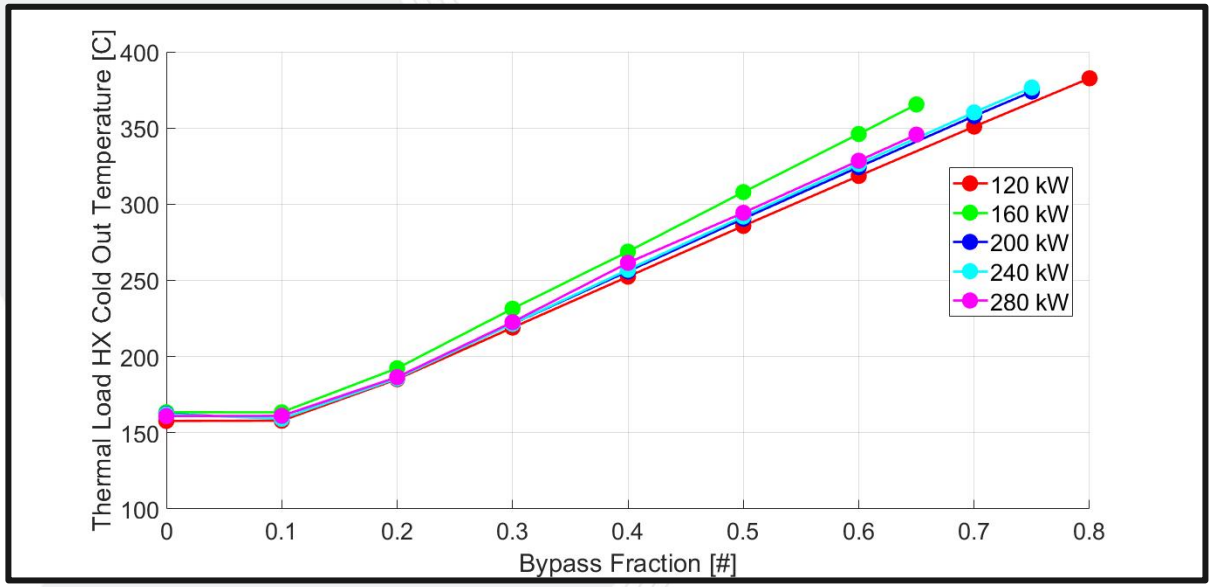


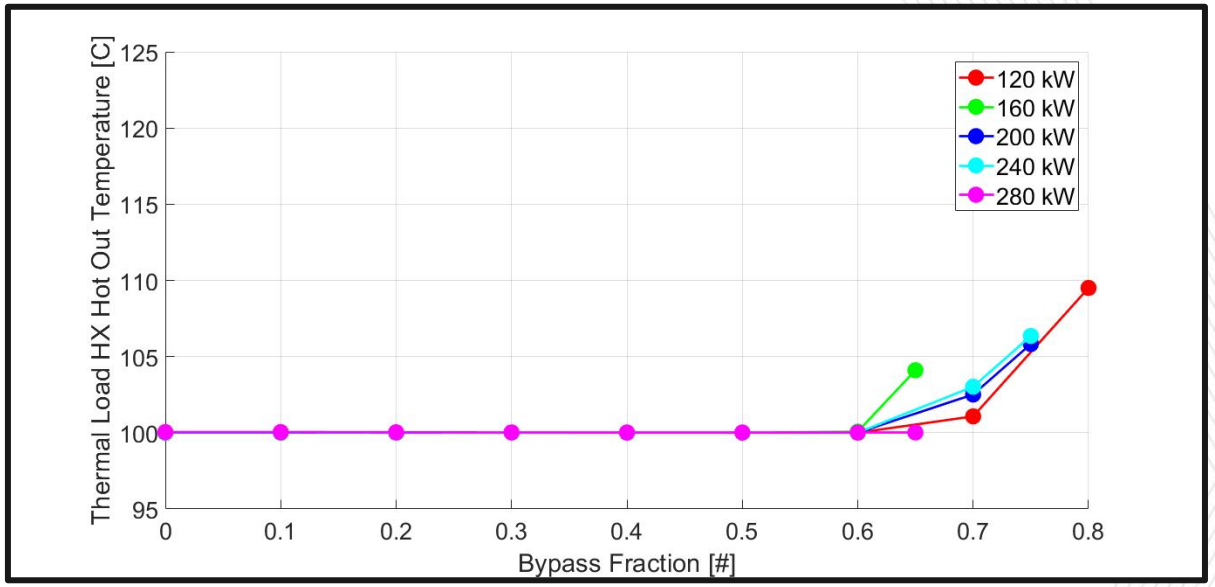


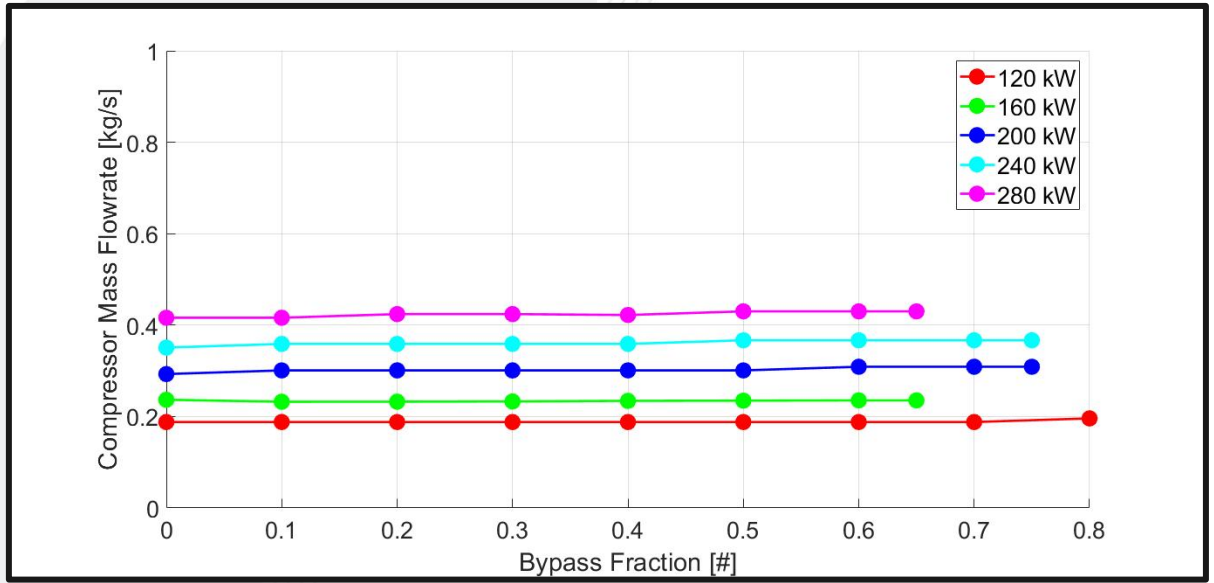


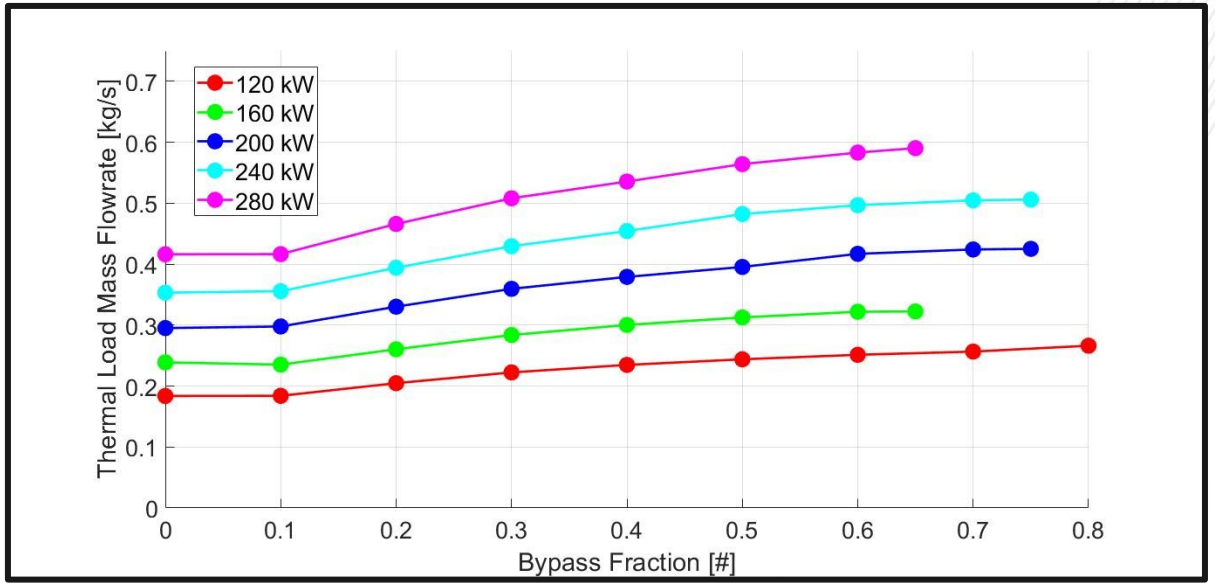
Preliminary Simulation Results: Additional Parameters

All x-Axes: Fraction of Fluid Bypassing Hot Side of Recuperator through Bypass Valve - All Legends: Total Power Supply of System



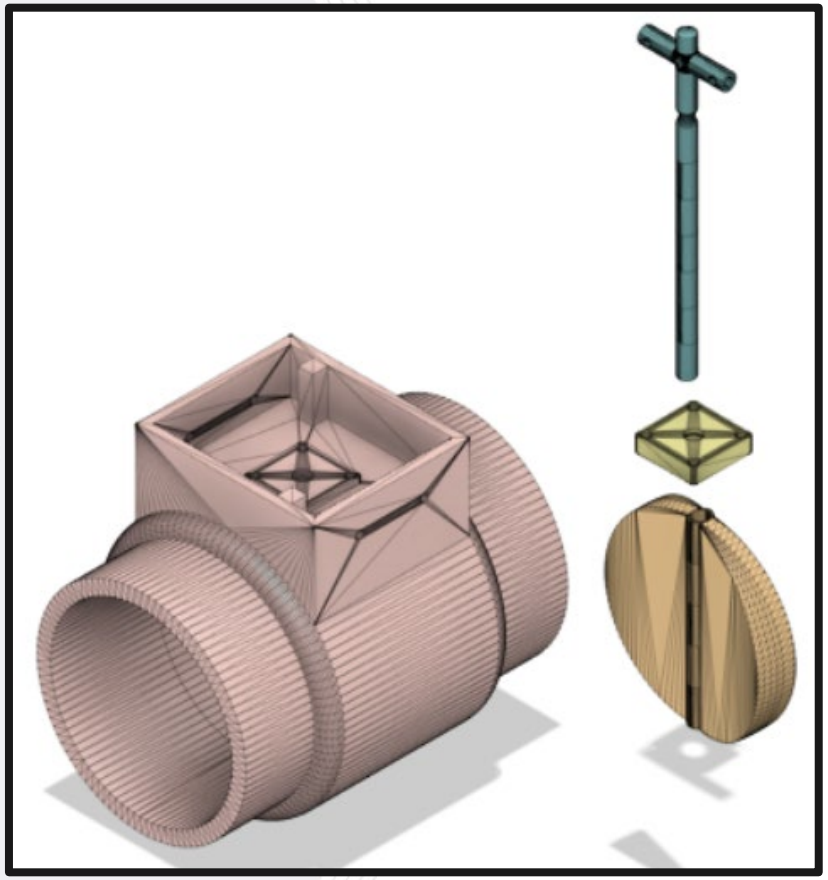






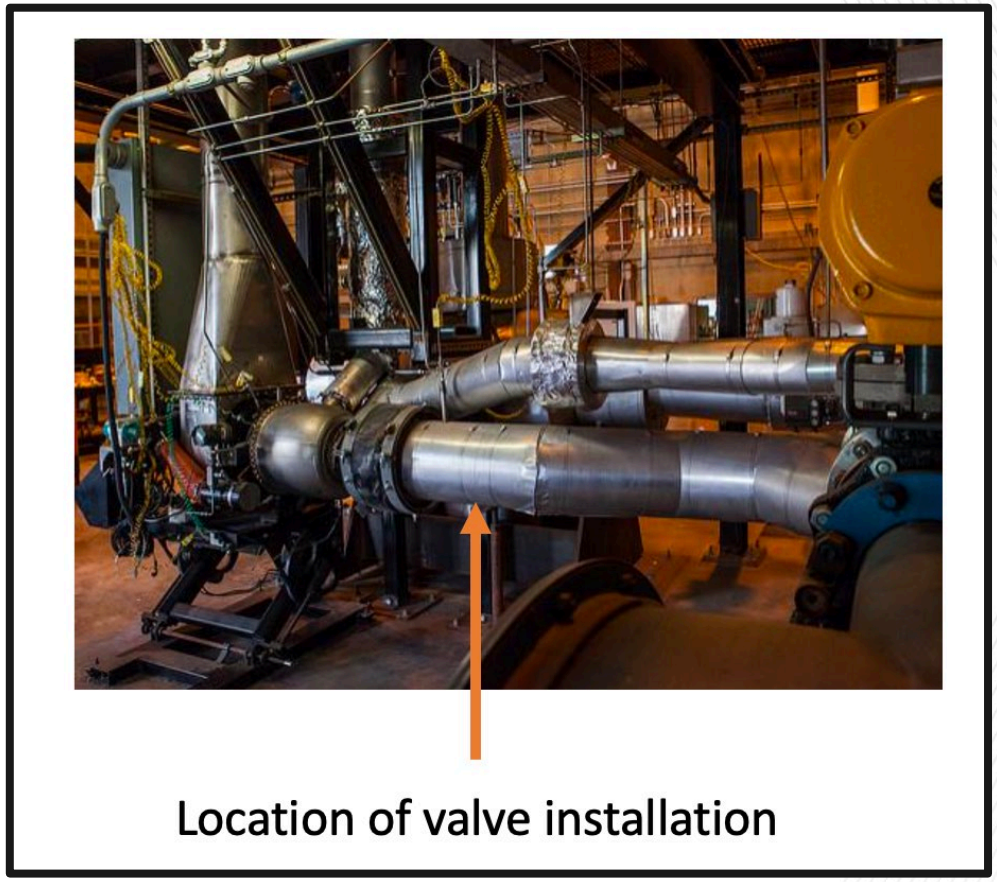
Bypass Valve Technology

Recuperator Bypass Valve Design



Actuation caused by springs composed of high-temperature resistant shape-memory alloy materials

Location of Valve Installation in the HyPer Cyberphysical System



Valve will be installed within HyPer to test its operational abilities and characteristics within realistic temperatures, pressures, and mass flows

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Conclusion and Future Work

Simulated cycle across a range of power supplies and recuperator bypass valve operations

Need to post-process data with heat supply standardization and quasi-steady-state dynamics in mind

Possibly collect more data at more power supply values

Designed and developed hot side recuperator bypass valve

Implementation of the valve in HyPer is imminent

Valve still needs to be characterized and modeled

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Thank you for listening to the presentation

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Any Questions?