MSFC-662

Recent Updates to the Fission Surface Power Primary Test Circuit (FSP-PTC)

Anne E. Garber

Abstract – *An actively pumped alkali metal flow circuit, designed and fabricated at the NASA Marshall Space Flight Center, underwent a range of tests at MSFC in early 2007. During this period, system transient responses and the performance of the liquid metal pump were evaluated. In May of 2007, the circuit was drained and cleaned to prepare for multiple modifications: the addition of larger upper and lower reservoirs, the installation of an annular linear induction pump (ALIP), and the inclusion of a closeable orifice in the test section. Modifications are now complete and testing has resumed. Performance of the ALIP, provided by Idaho National Laboratory (INL), is the subject of the first round of experimentation. This presentation details the physical changes made to the FSP-PTC and the current test program.*

MSFC-648

Recent Updates to the Fission Surface Power Primary Test Circuit (FSP-PTC)

Anne E. Garber

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Nuclear Systems Branch/ER24
Early Flight Fission – Test Facility (EFF-TF)

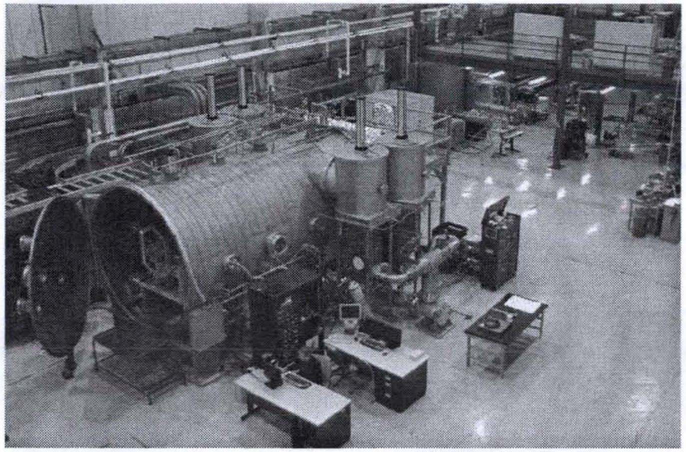
Presentation Summary

- Early Flight Fission Test Facility (EFF-TF)
- Objectives
- SNaKC
- Pump Performance Test Results
- System Cleanout
- Circuit Modifications
- Summary

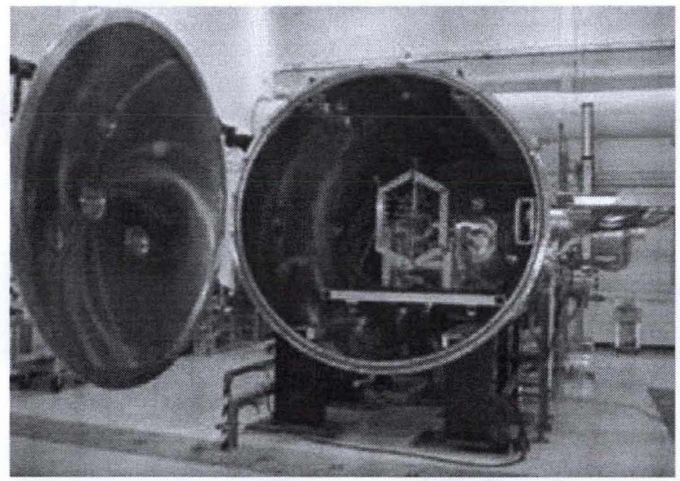
National Aeronautics and
Space Administration

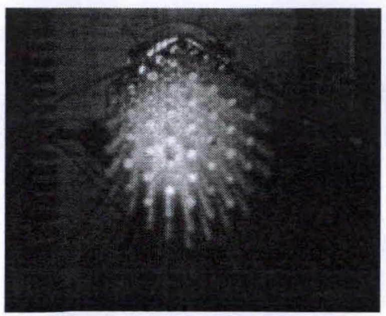
Realistic Non-Nuclear Testing of Nuclear Systems: From Paper to Reality

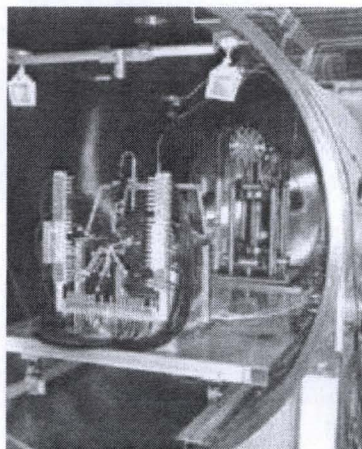
George C. Marshall Space Fight Center

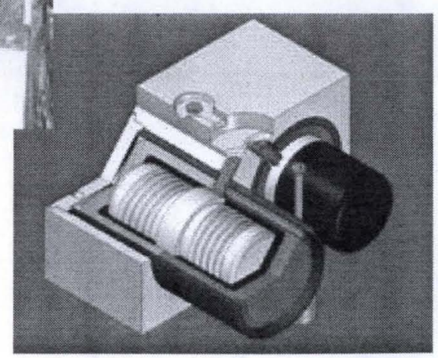


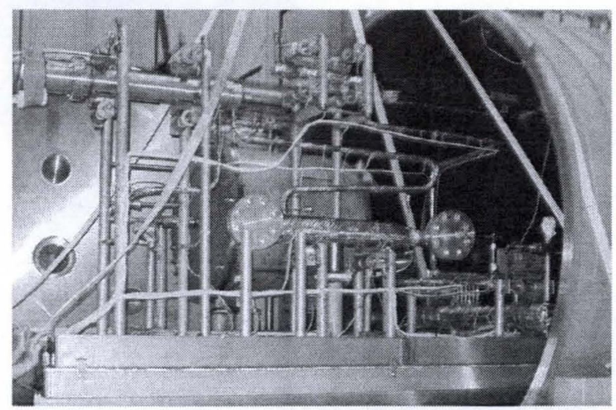
The Early Flight Fission Test Facility (EFF-TF) is the only <u>operating</u> facility in the U.S. capable of performing realistic thermal hydraulic testing of nuclear systems using non-nuclear (electrical) heat sources.











Development of a similar test bed for General Purpose Heat Sources (GPHS) builds on success of the EFF-TF and ESTF.

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History
Early Flight Fission Test Facility

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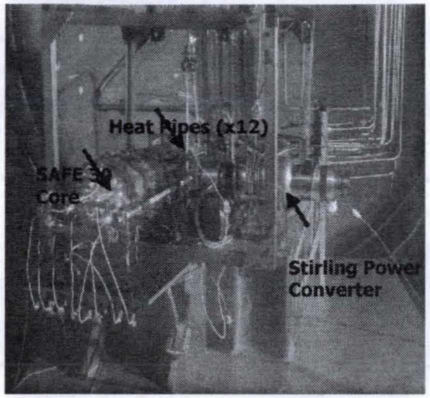
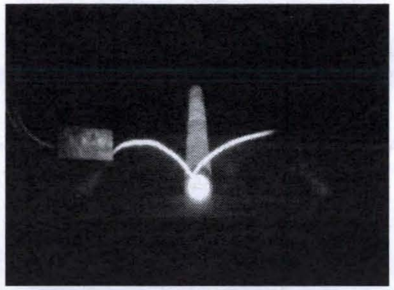
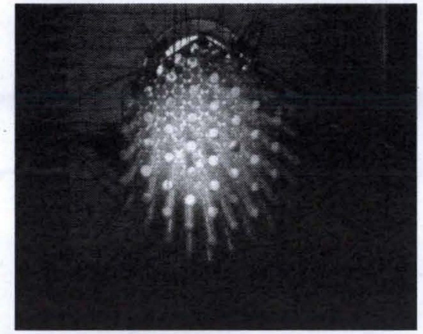
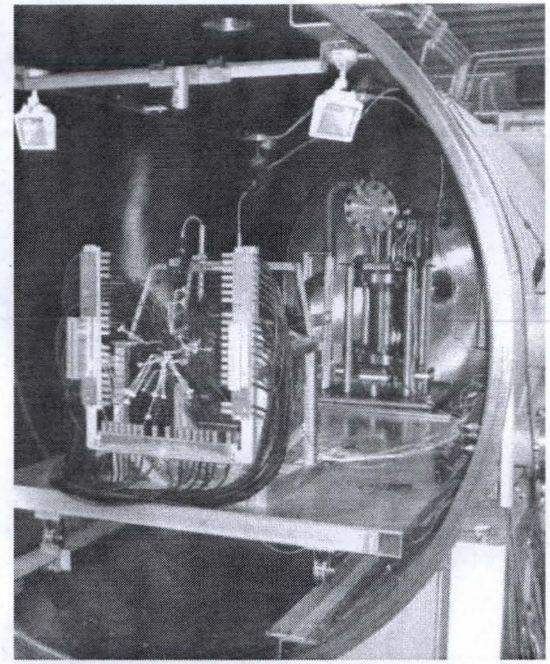
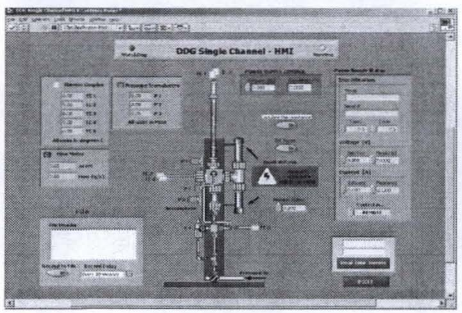
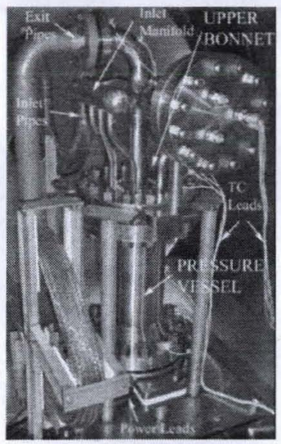


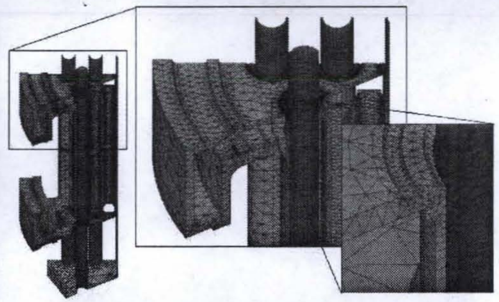


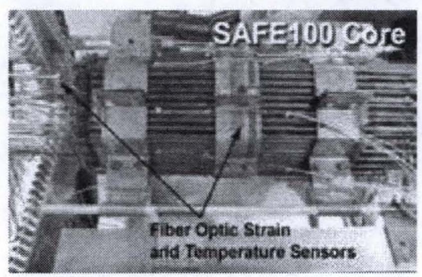


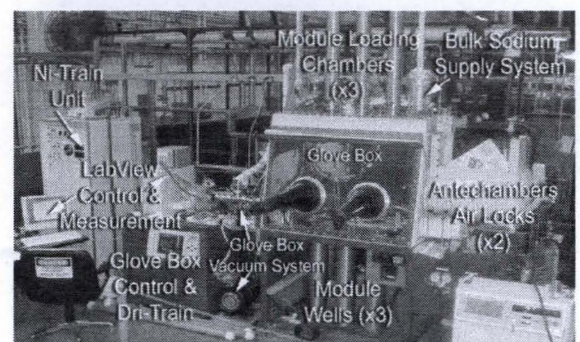


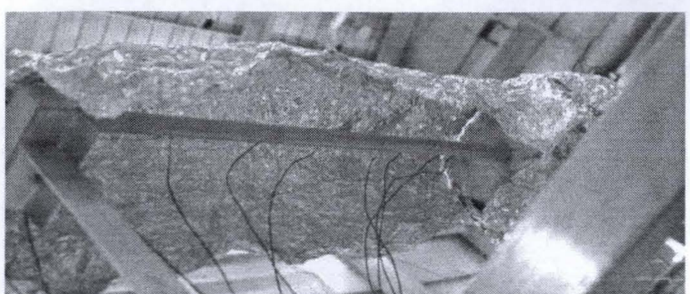








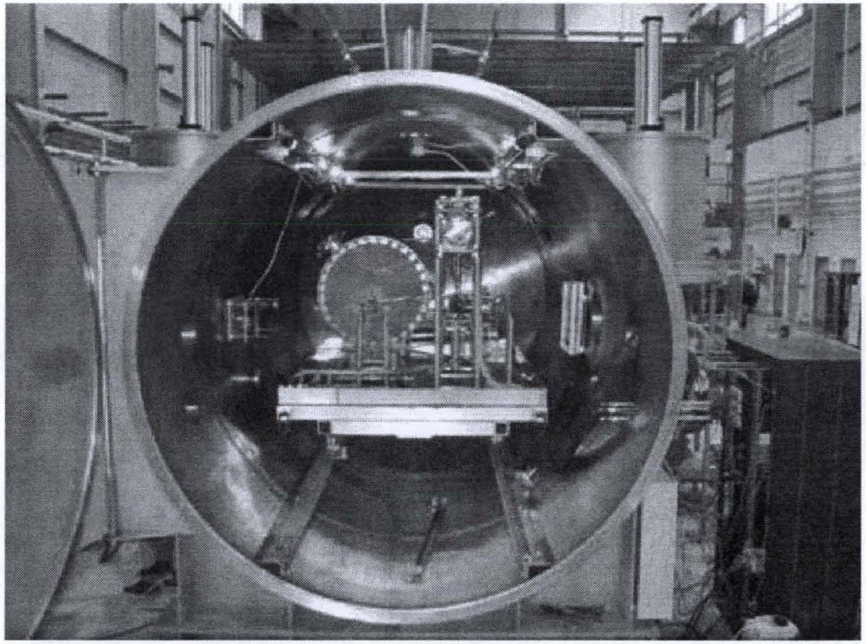




Working closely with customer to help devise/design useful facilities and perform tests to help customer turn ideas from paper to reality

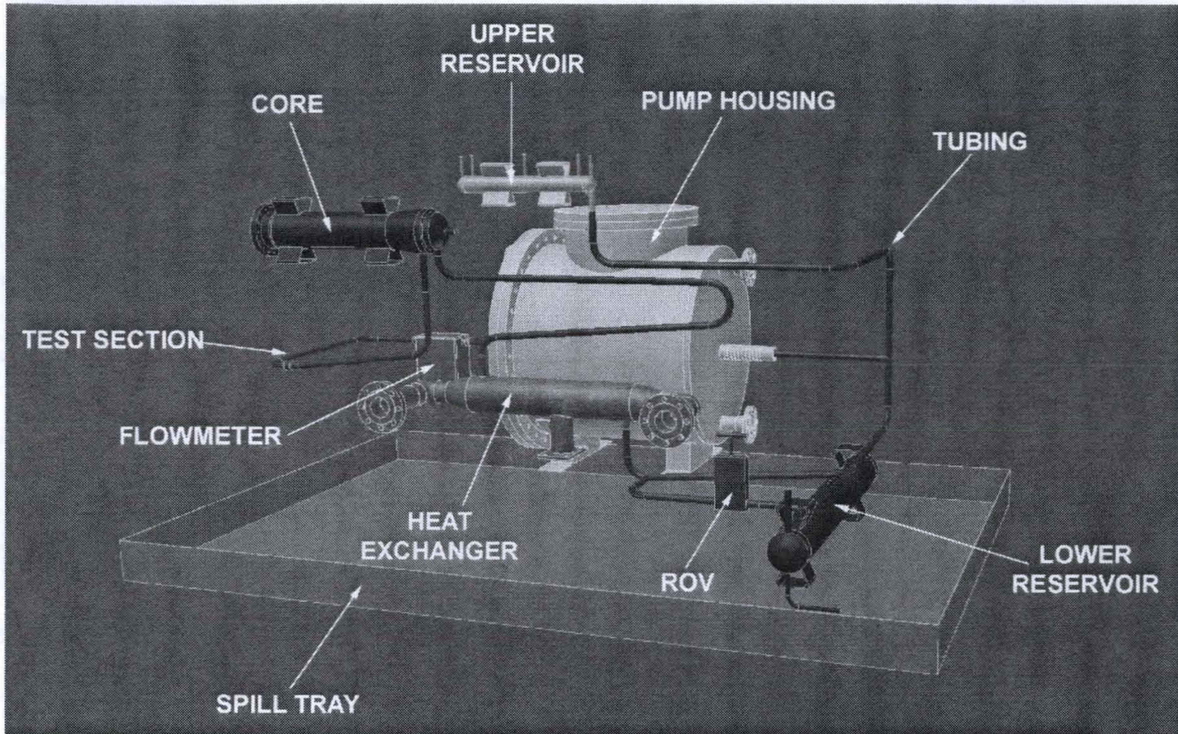
SNaKC

- A reactor concept shall be filled with liquid metal (NaK) and thermal hydraulically tested. This testing will:
  - Provide the EFF-TF team with hands-on liquid metal systems experience.
  - Assist in the design of the second generation Fission Surface Power Primary Test Circuit (FSP-PTC) and its subsystems.
- Specific objectives:
  - Inclusion of a “test section” to evaluate components.
  - Preliminary flow analysis using simulation.
  - Experimental data will flow into second-generation circuit design.
  - Personnel trained in the handling of NaK.
  - Procurement and integration of a liquid metal cleaning system to enhance operation.

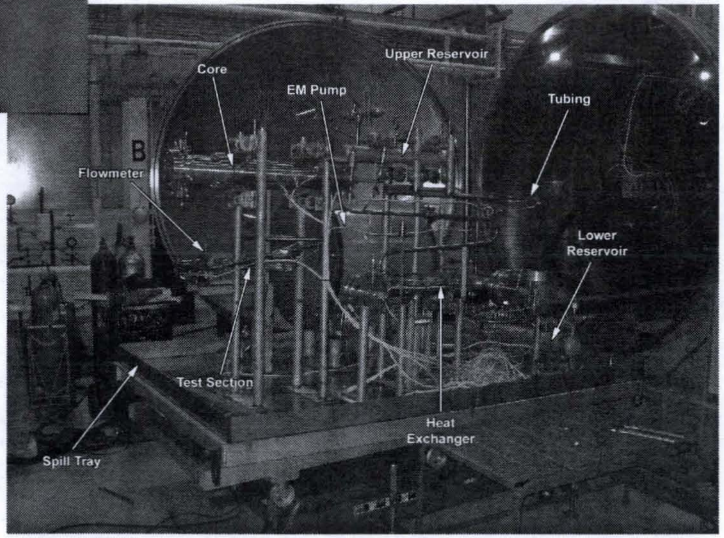


Liquid metal system inside 9-ft vacuum chamber

SNaKC

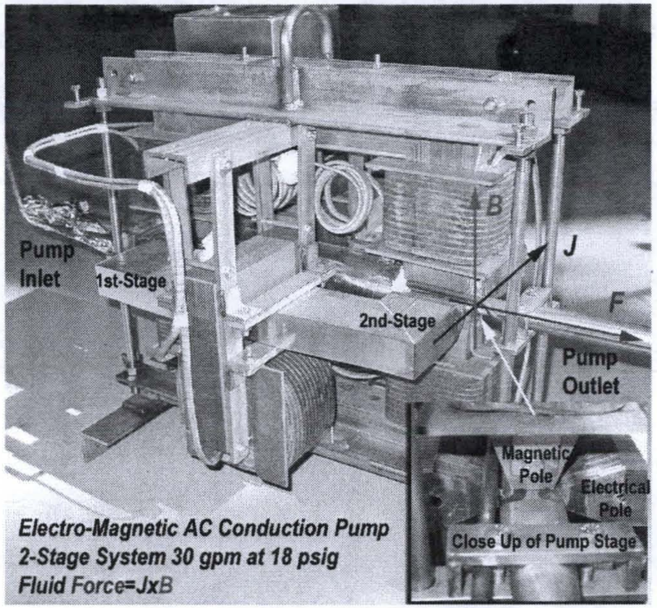


- 1/3 partial core from 100 kWt LANL design study
- NaK-to-GN_2 heat exchanger
- EM pump capable of developing 15 psi at ~23 GPM
- 20 psi at 1000°F
- All wetted components are stainless steel

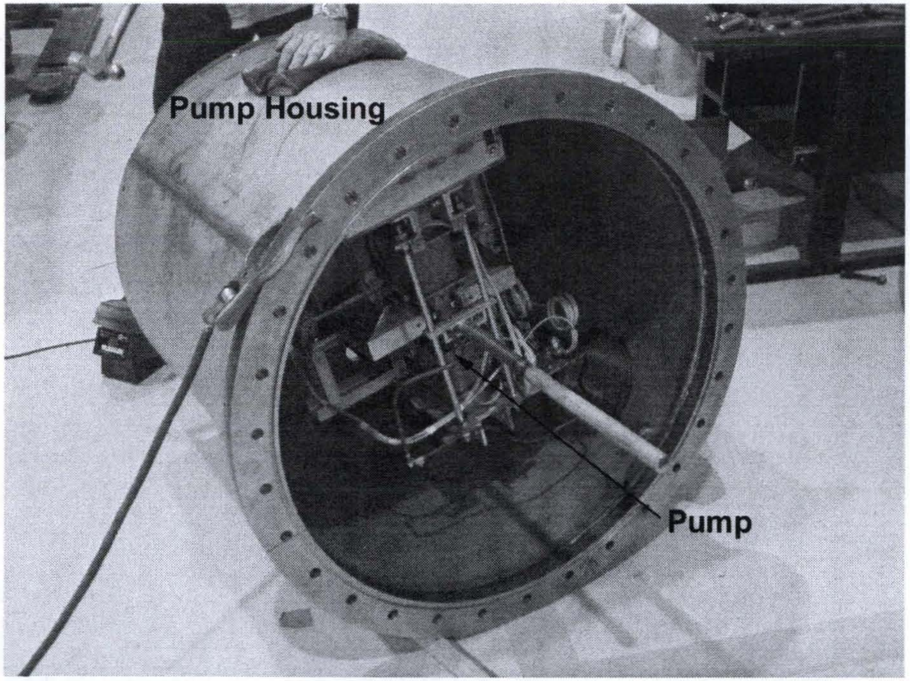


SNaKC

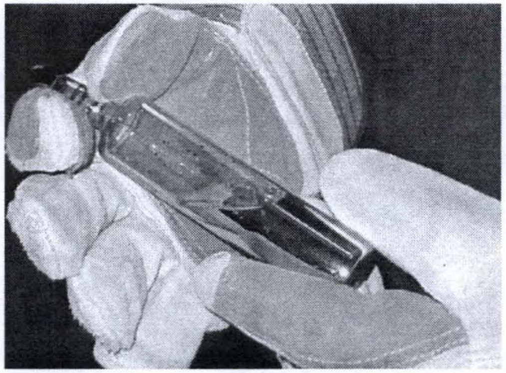
- Electromagnetic pump
  - Style-VI AC conduction EM pump
  - No moving parts; operates on F=JxB principle
  - Capable of generating ~1.5 kg/s mass flow rate
  - GN_2 flows through housing for pump cooling



EM pump



EM pump in housing



Pump Performance Test Results

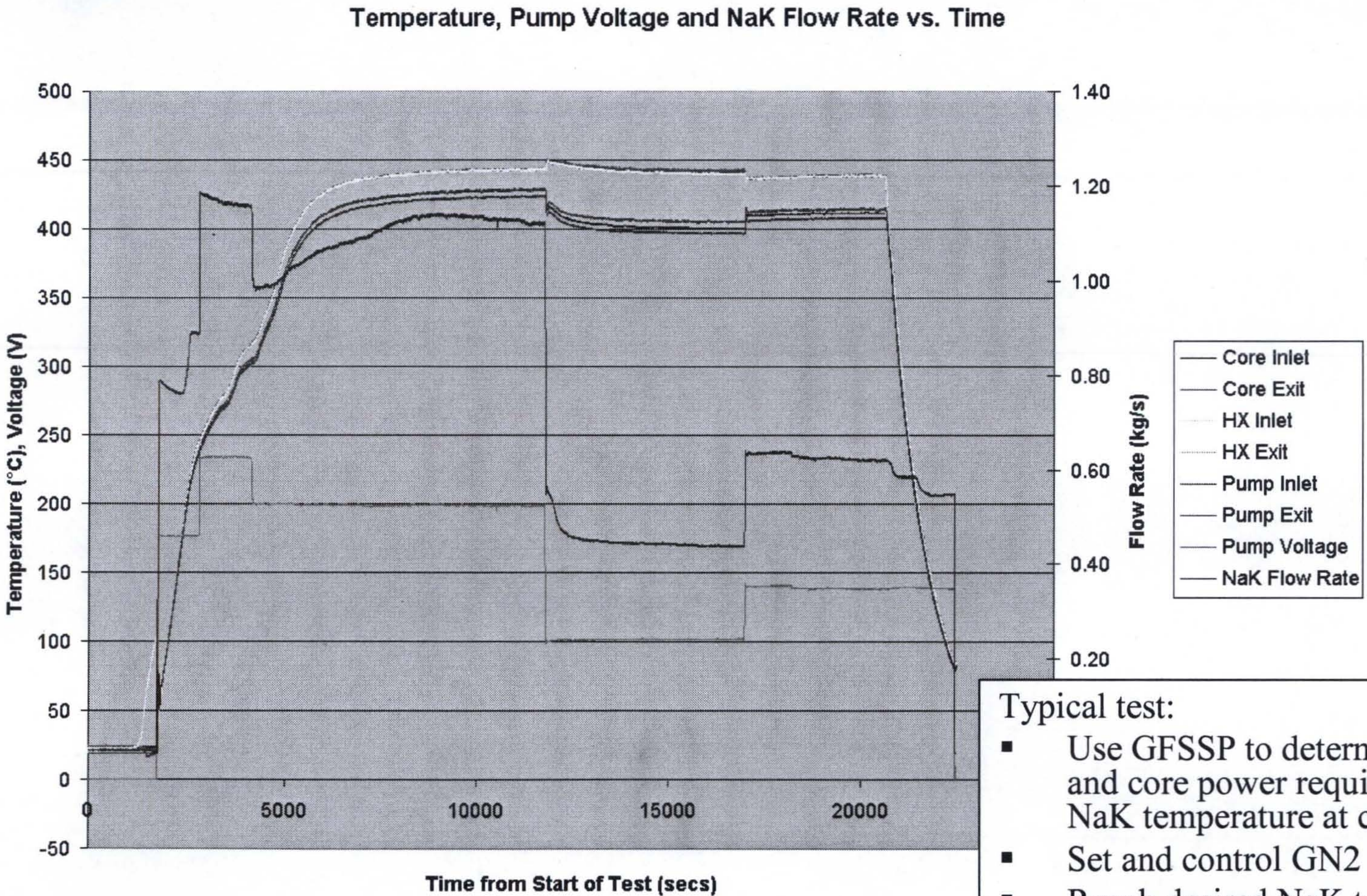
Pump Performance Test Matrix

		EM Pump Voltage			
		100V	140V	200V	max V
NaK Flow Temp	350°C	4	2	3	1
	375°C	3	1	4	2
	400°C	1	3	2	4
	425°C	2	4	1	3
	450°C	4	2	3	1
	475°C	3	1	4	2
	500°C	1	3	2	4
	525°C	2	4	1	3
	538°C	4	2	3	1

- Test matrix was designed to characterize the developed flow rate, pressure, and pump efficiency over a range of pump voltages and NaK temperatures

- Pump behavior for NaK-56 at 1060°F (571°C) provided by vendor
- Pump efficiency increases at ~800°F (427°C)
- Tested ranges may be varied as needed

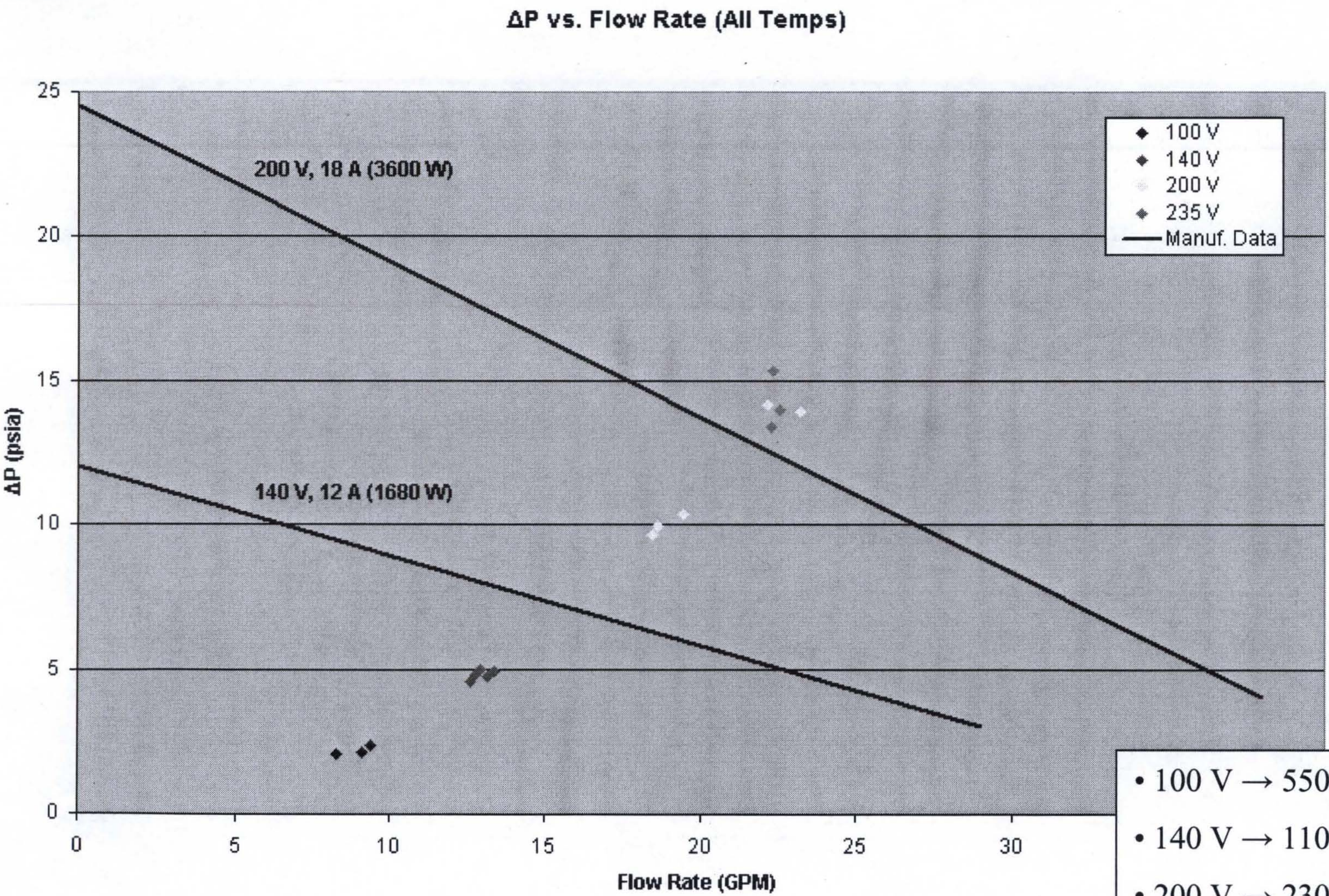
Pump Performance Test Results



Typical test:

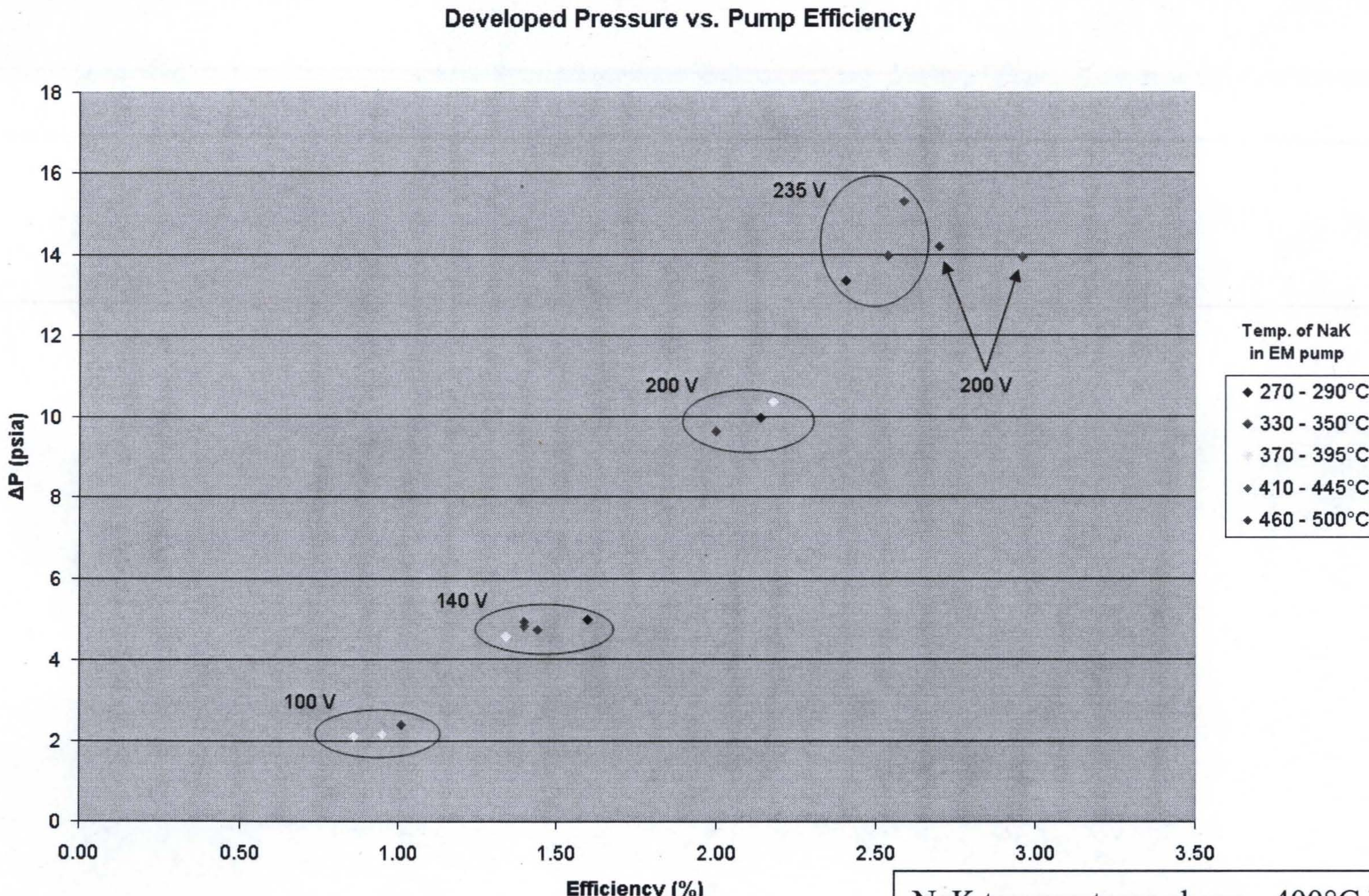
- Use GFSSP to determine GN2 flow rates and core power required to reach a desired NaK temperature at core exit
- Set and control GN2 flow rate
- Reach desired NaK temperature
- Change pump voltage (NaK flow rate) to generate multiple data points in one temperature range
- Core power for this test set to 20 kW

Test Results



- 100 V → 550 W
- 140 V → 1100 W
- 200 V → 2300 W, 2900 W
- 235 V → 3300 W

Test Results



NaK temperatures above ~400°C have an effect on pump efficiency, though not at all pump power levels

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Test Results

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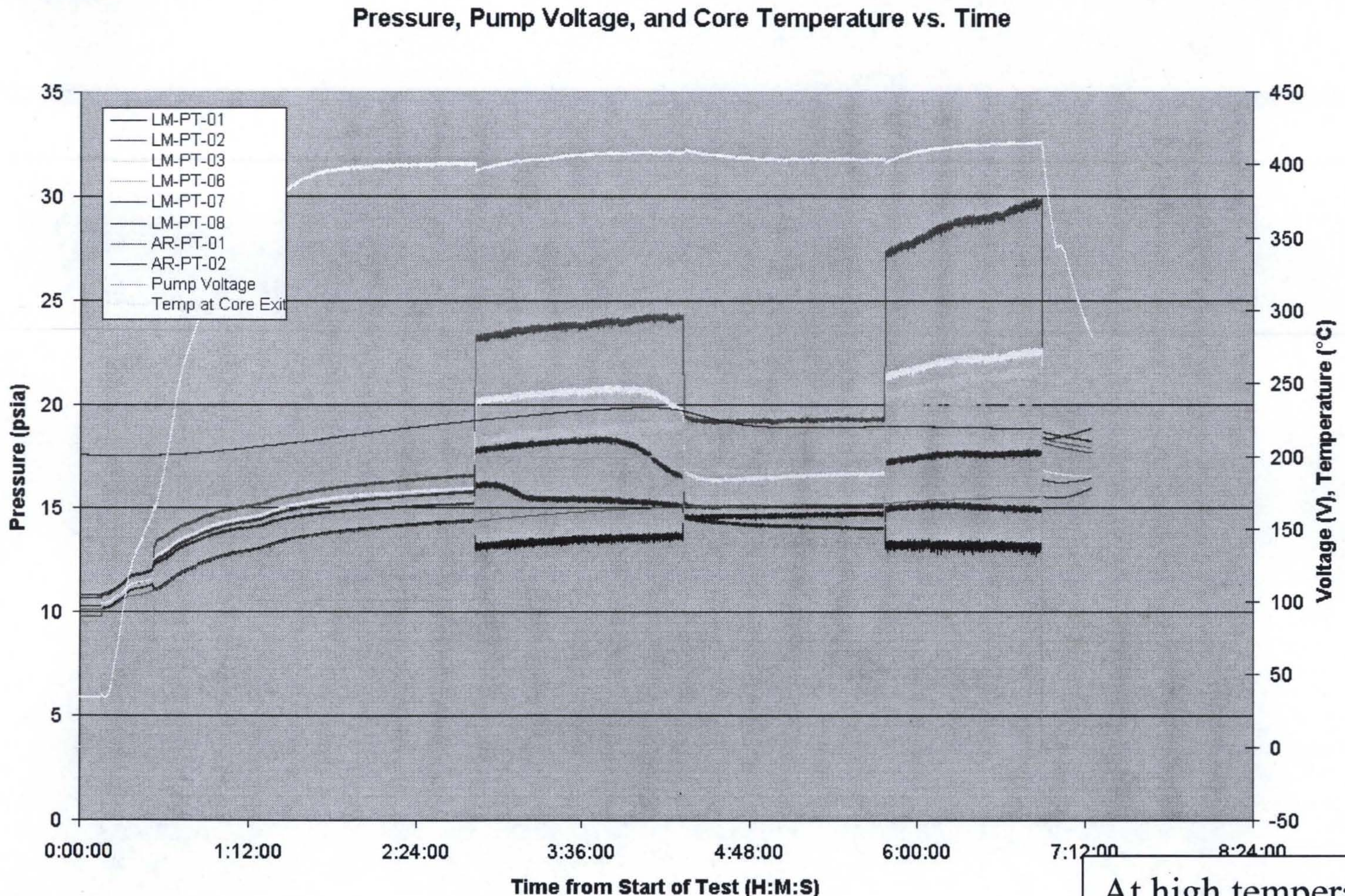
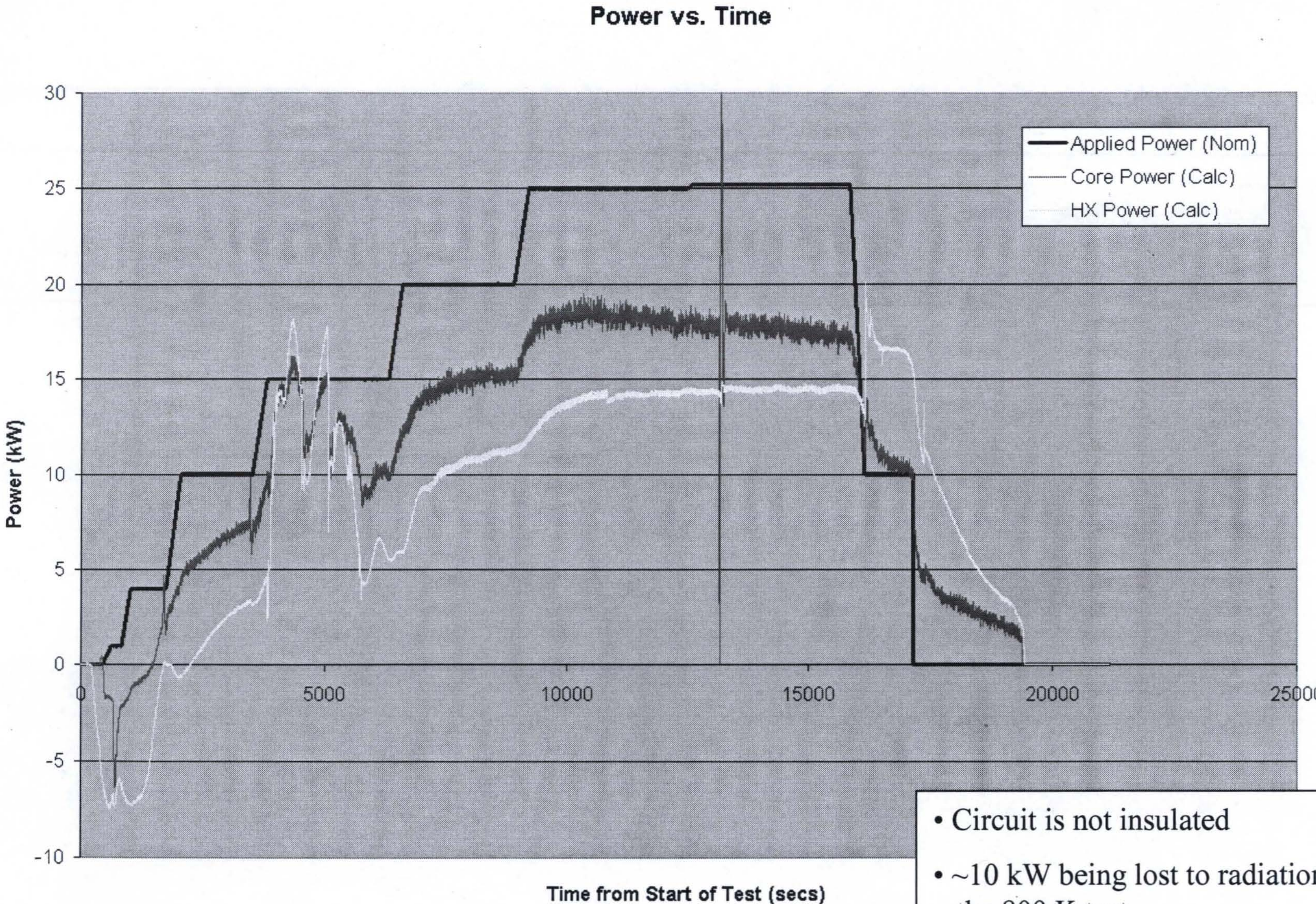


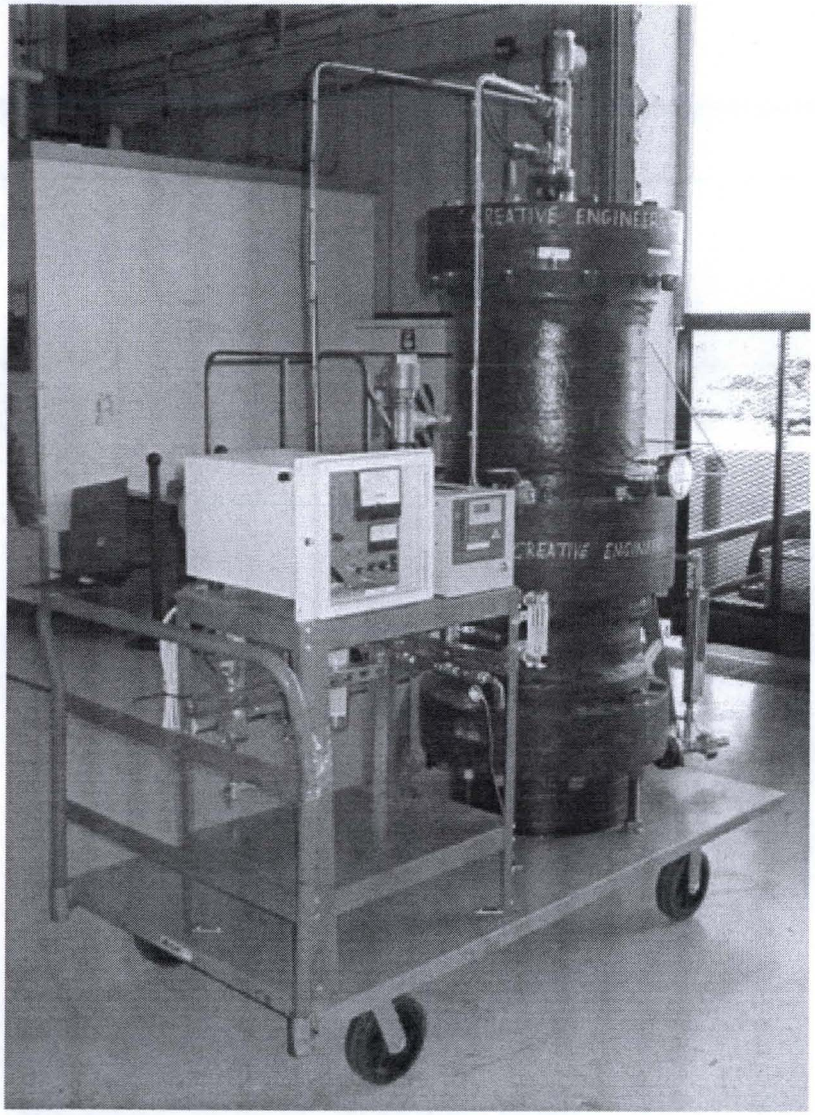
At high temperatures and max pump voltage, pump pressure had not reached steady state when the test was shut down.

Test Results

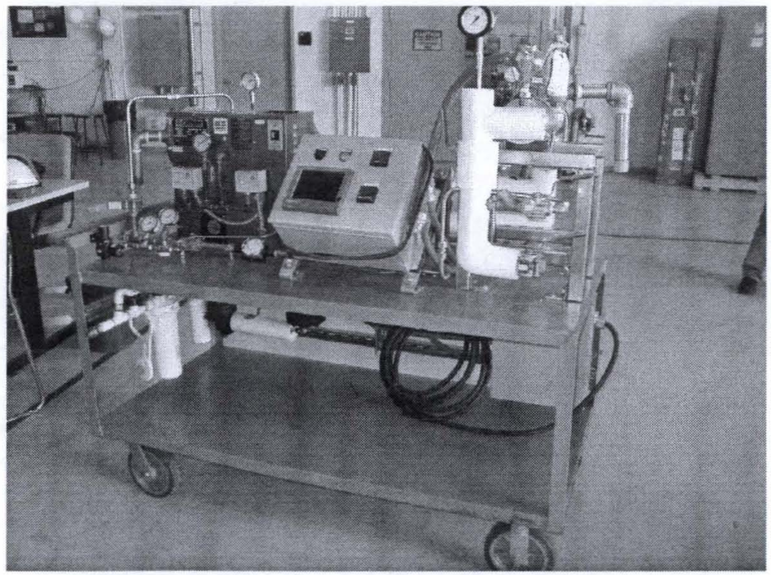


- Circuit is not insulated
- ~10 kW being lost to radiation in the 800 K test

System Cleanout

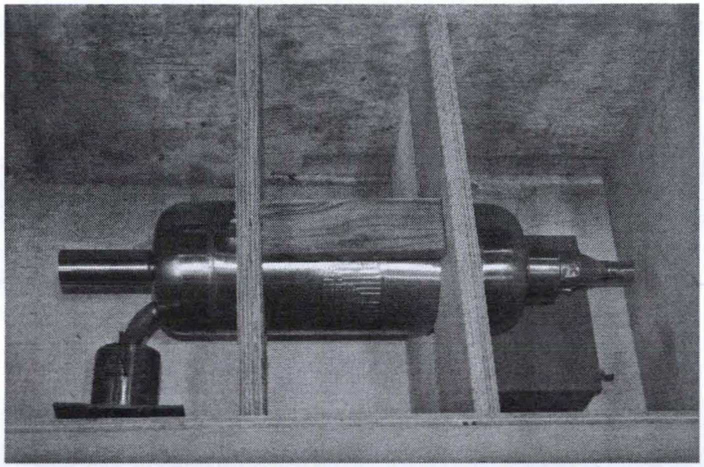


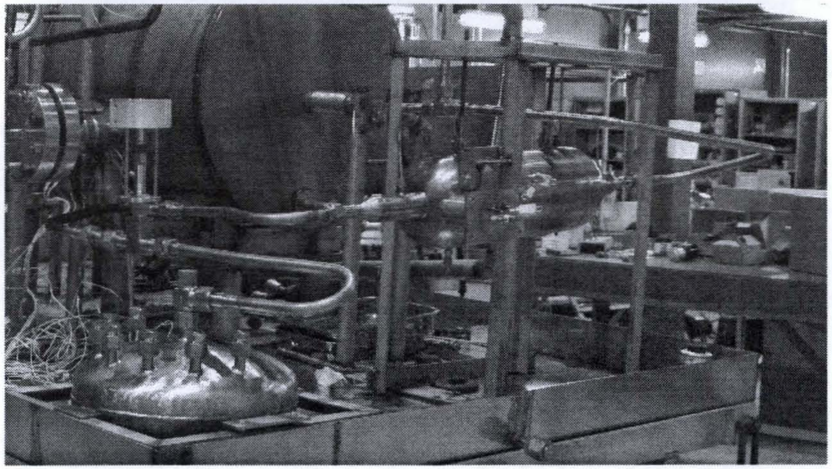
- System was drained and cleaned of residual NaK
  - Mixture of dry steam and superheated nitrogen
  - Rate of hydrogen production monitored
  - Water flush



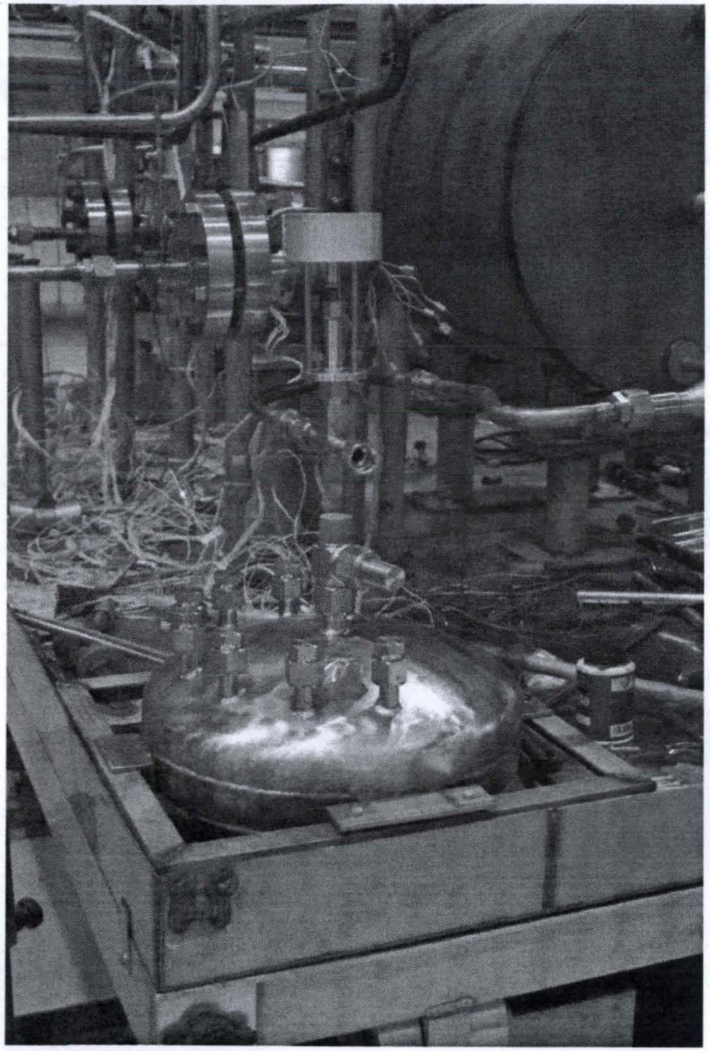
Circuit Modifications

- Annular Linear Induction Pump (ALIP)
  - Provided by INL
  - Originally used to pump sodium
  - Nominally capable of developing higher flow rates and pressures than the EM pump
- How it works
  - Current in the conducting fluid is induced by a traveling magnetic field
  - Time-varying current produces the magnetic field; magnetic field induces currents in the NaK; currents interact with field to produce a Lorentz force
- Can tolerate higher temperatures than conduction-style pumps

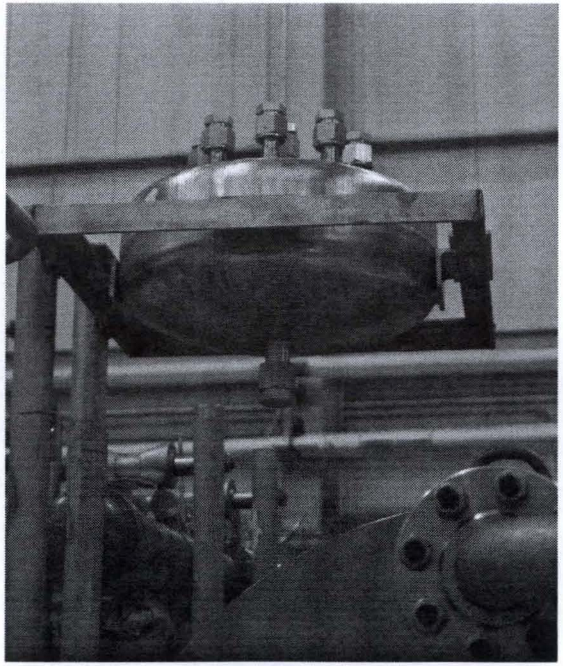




Circuit Modifications

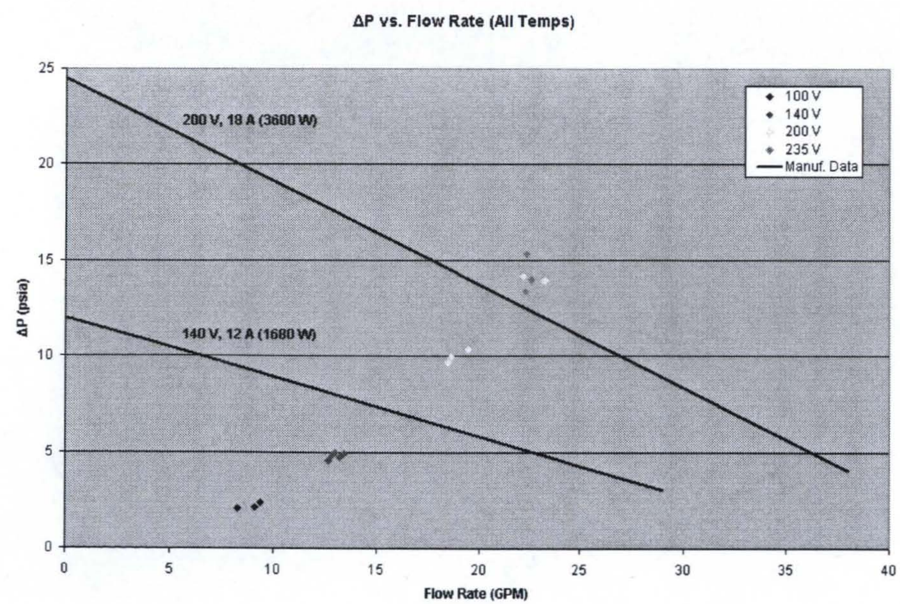


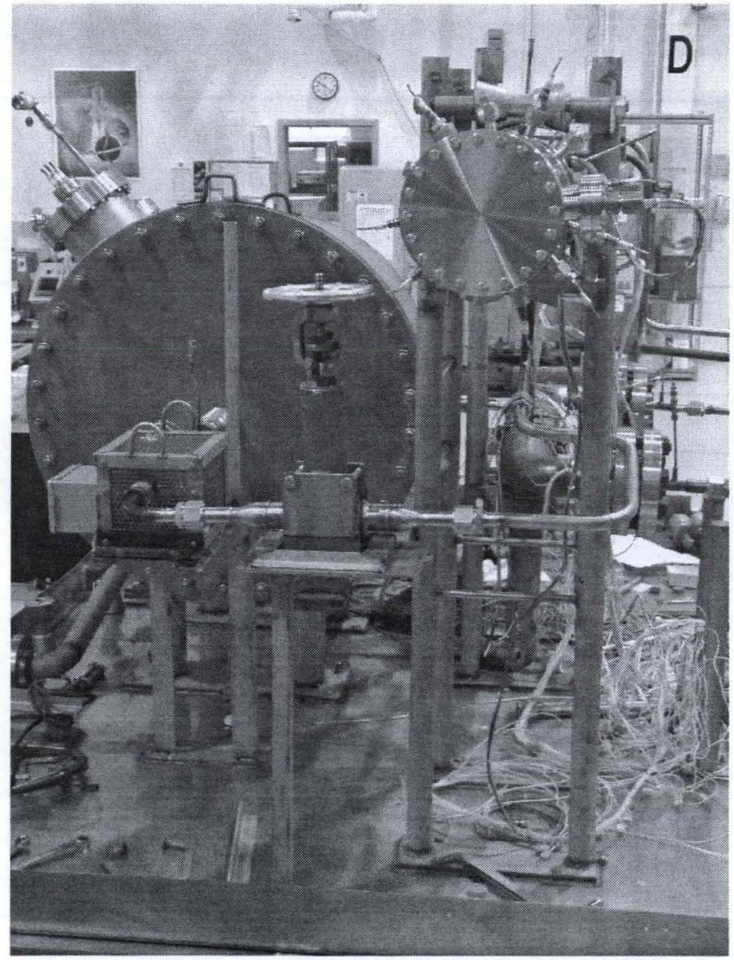
- Inclusion of ALIP and new tubing runs increased circuit volume
- Fill/drain reservoir is large enough to accommodate addition of further components
- Larger upper reservoir to prevent overflow in the event of circuit “burping”



Circuit Modifications

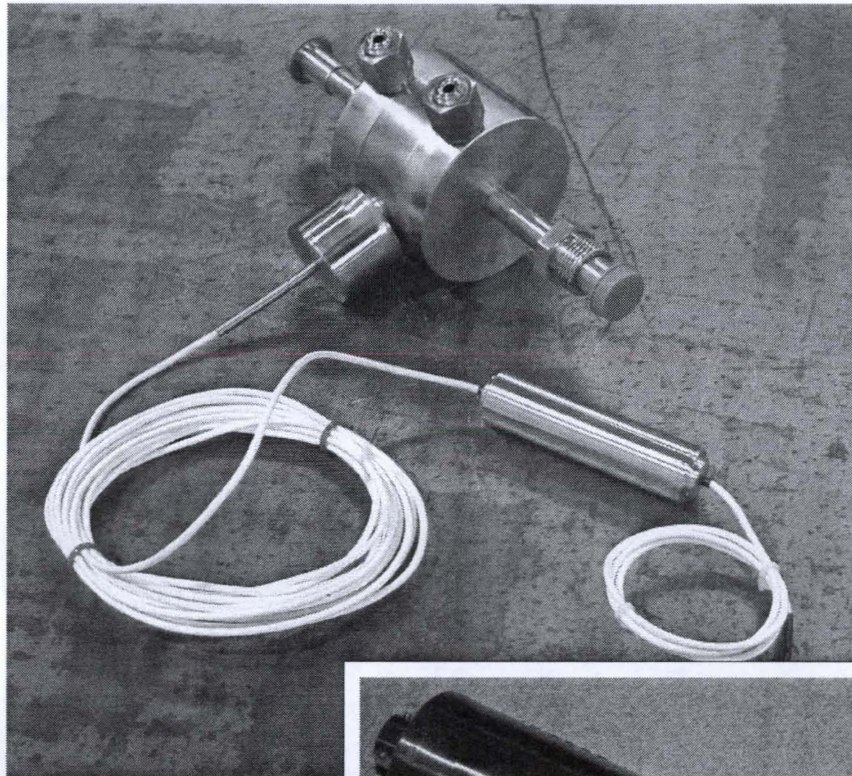
- Throttling valve installed in the test section
- Large flow-through area
- Will allow for the generation of a pump performance curve at a single power setting

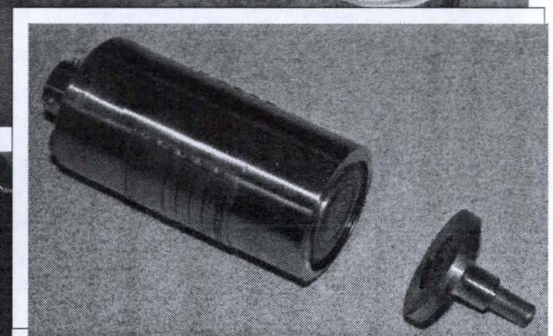


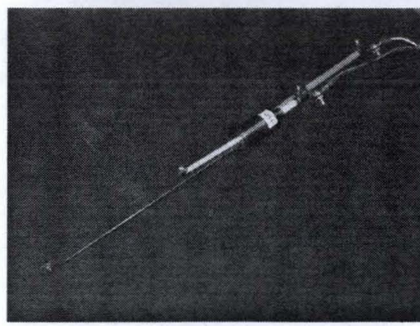


Circuit Modifications

- Pressure Transducers
  - Differential pressure measurements across core, EM pump and ALIP
  - Flow-through design for cleanout; allows re-use of the instrument
- Thermocouples
  - Use of sheathed thermocouples and RTDs
  - Noise is considerably reduced
  - Power balance is highly sensitive to temperature
- Level sensors
  - Dynamic sensors developed for upper and lower reservoirs

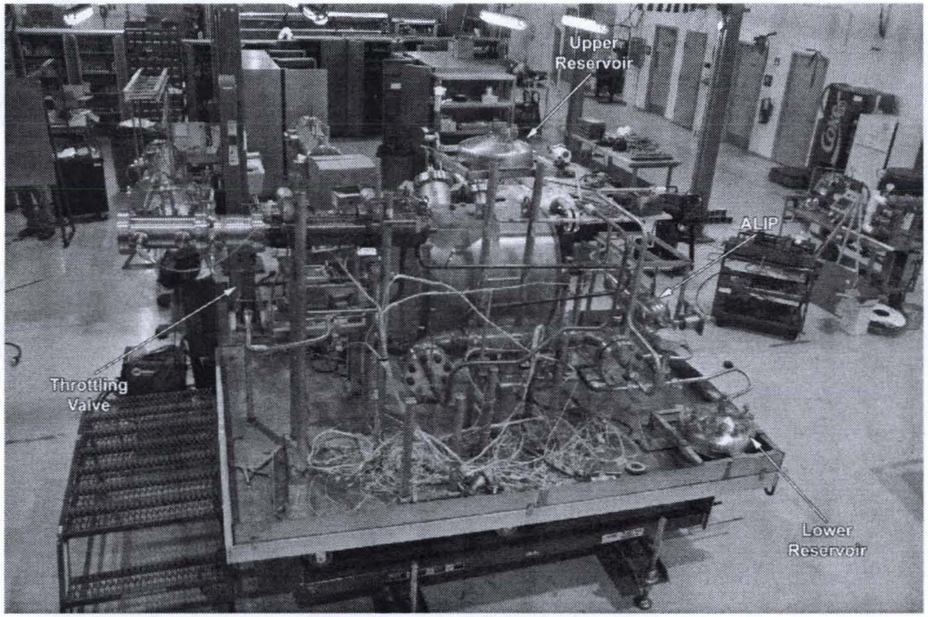






Summary

- First round of testing was successfully completed
  - Test article has been brought up to a maximum of 525°C (800 K) at 25 kW
  - Flow rates of 23 GPM (1.2 kg/sec) have been reached with 15 psi ΔP
- Many lessons learned regarding the filling and draining of the circuit, NaK flow, changing out of components, use of instrumentation and system cleanout
- Circuit has been modified to include the ALIP, throttling valve, and new instrumentation
- NaK will be introduced to the system in mid-January and testing will resume
- Goal is to characterize the performance of the ALIP



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Acknowledgments

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