Initial Testing of the Stainless Steel NaK-Cooled Circuit (SNaKC)

Abstract. An actively pumped alkali metal flow circuit, designed and fabricated at the NASA Marshall Space Flight Center, is currently undergoing testing in the Early Flight Fission Test Facility (EFF-TF). Sodium potassium (NaK) was selected as the primary coolant. Basic circuit components include: simulated reactor core, NaK to gas heat exchanger, electromagnetic liquid metal pump, liquid metal flowmeter, load/drain reservoir, expansion reservoir, test section, and instrumentation. Operation of the circuit is based around the 37-pin partial-array core (pin and flow path dimensions are the same as those in a full core), designed to operate at 33 kWt. This presentation addresses the construction, fill and initial testing of the Stainless Steel NaK-Cooled Circuit (SNaKC).

Initial Testing of the Stainless Steel NaK-Cooled Circuit (SNaKC)

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

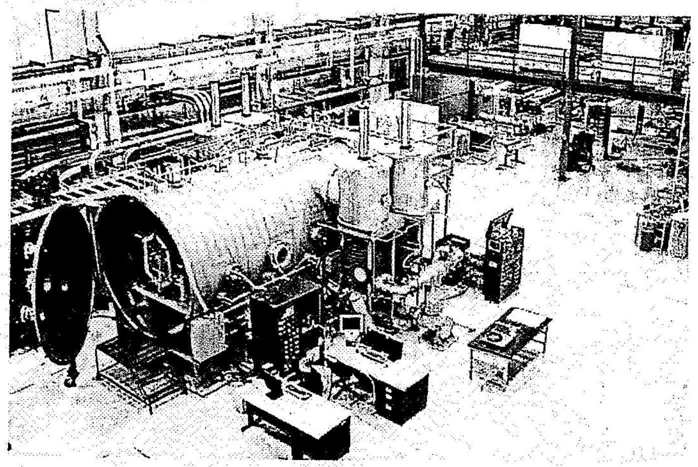
Presentation Summary

- Early Flight Fission Test Facility (EFF-TF)
- Test Objectives
- Test Configuration
- Instrumentation
- Initial Fill and Test
- Test Results
- Summary

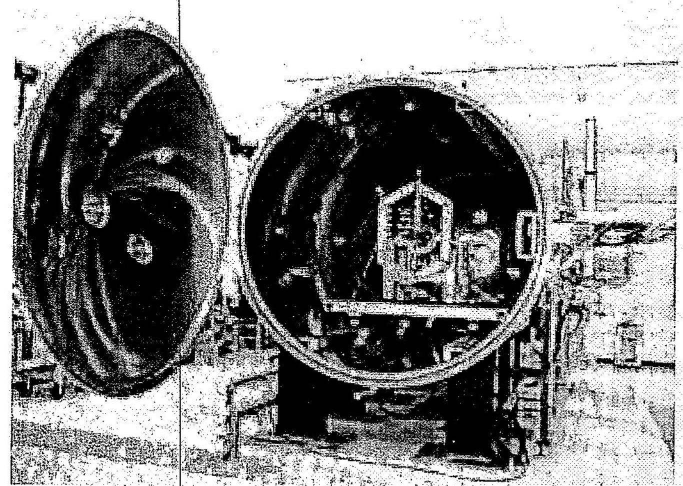
National Aeronautics and Space Administration

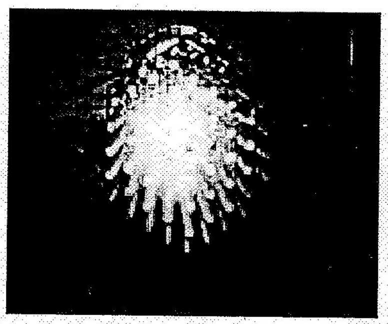
Realistic Non-Nuclear Testing of Nuclear Systems: From Paper to Reality

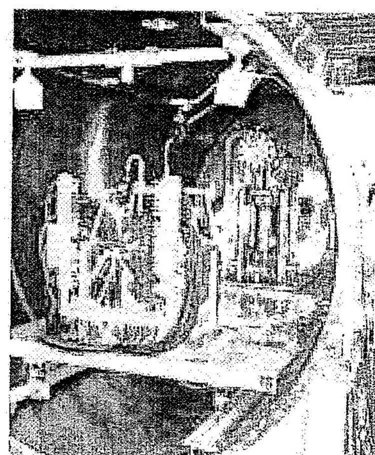
George C. Marshall Space Fight Center

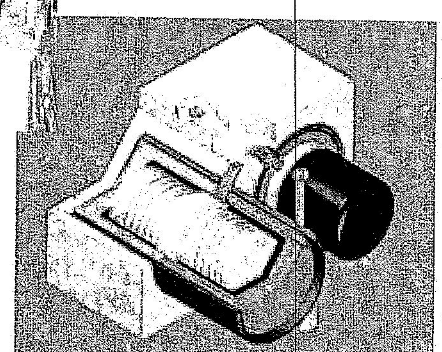


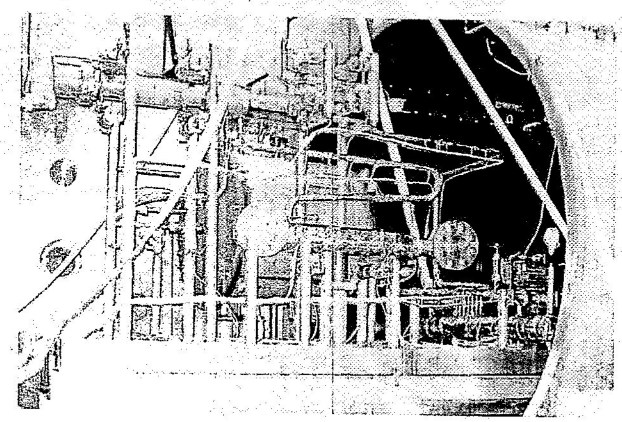
The Early Flight Fission Test Facility (EFF-TF) is the only operating facility in the U.S. capable of performing realistic thermal hydraulic testing of nuclear systems using non-nuclear (electrical) heat sources.











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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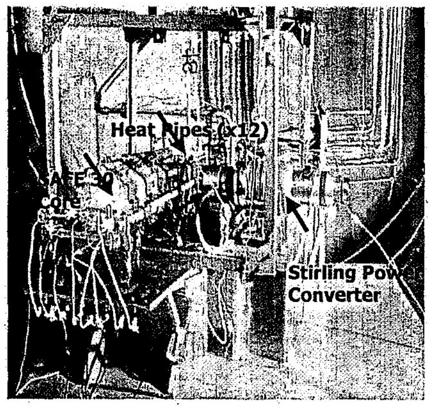
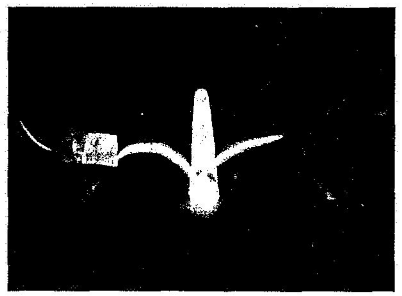
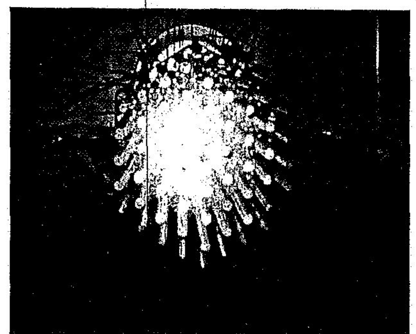
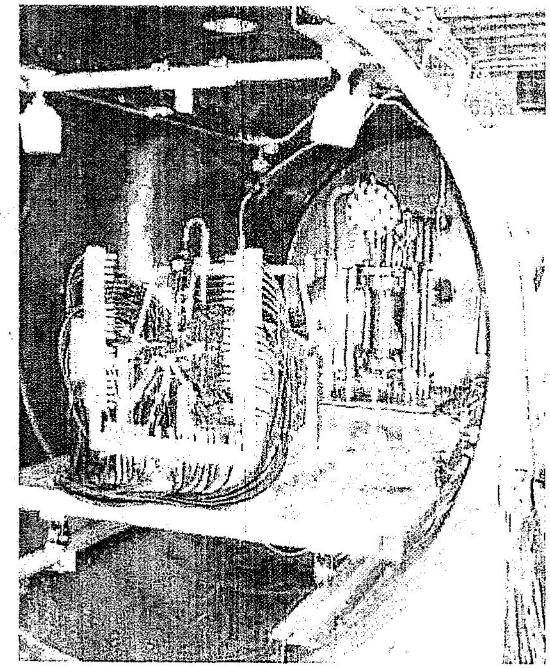
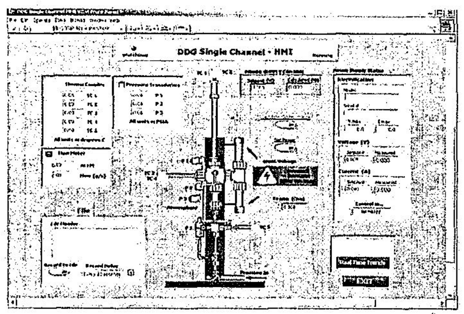
History
Early Flight Fission Test Facility

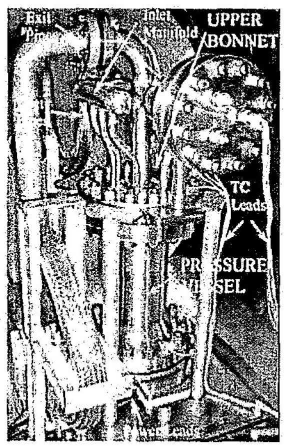


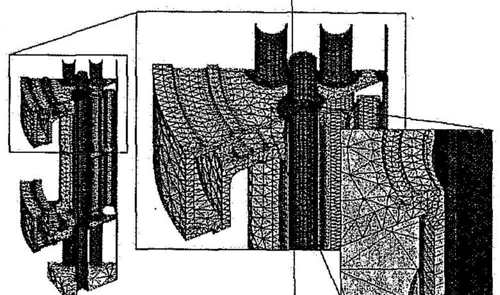


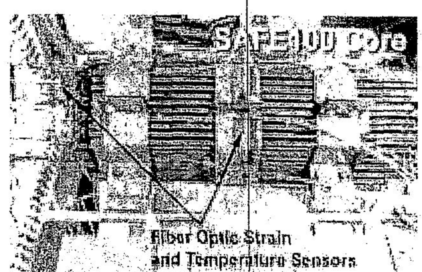


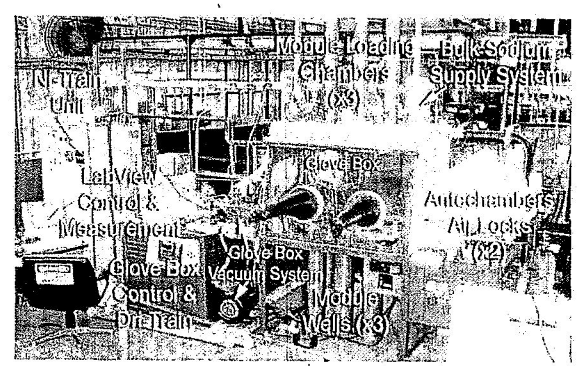










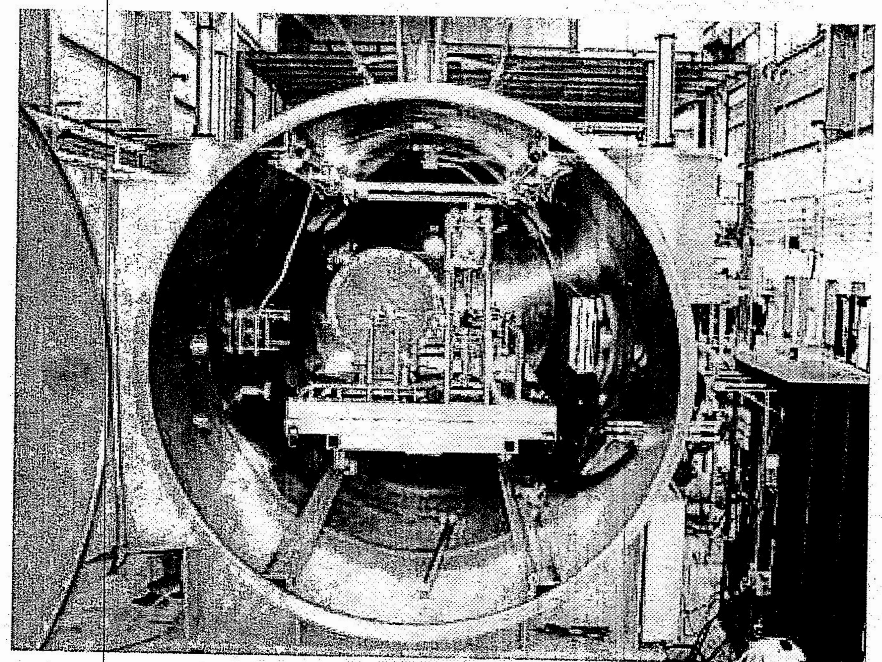


Working closely with customer to help devise/design useful facilities and perform tests to help customer turn ideas from paper to reality

Test Objectives

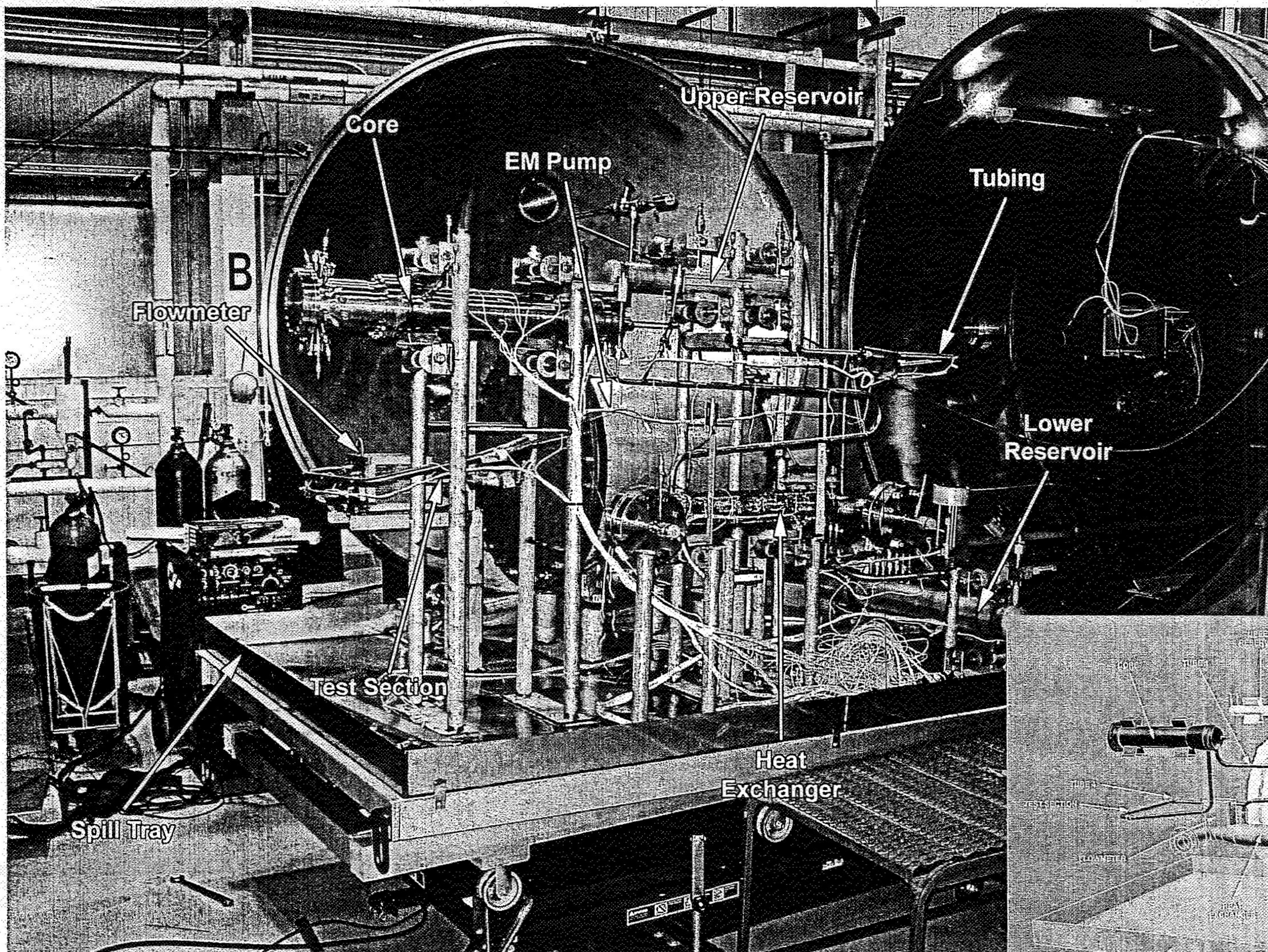
- A reactor concept shall be filled with liquid metal (NaK) and thermal hydraulically tested. This testing will:
  - Provide the EFF-TF team with hands-on liquid metal systems experience.
  - Assist in the design of the Fission Surface Power Primary Test Circuit (FSP-PTC) and its subsystems.

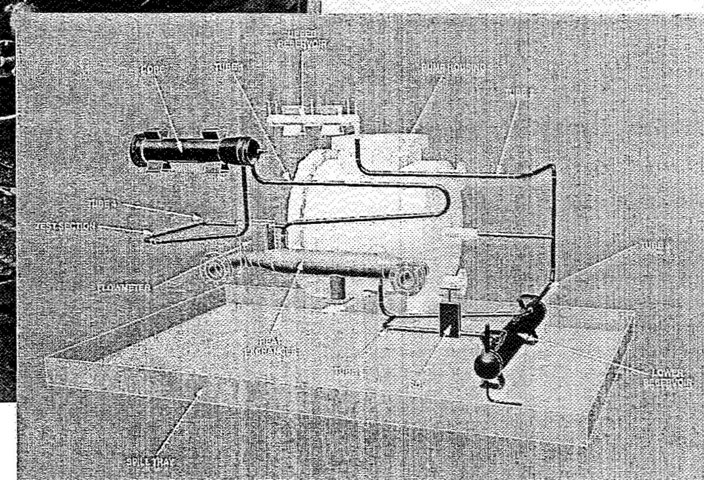
- Specific objectives:
  - Inclusion of a "test section" to evaluate components.
  - Preliminary flow analysis using simulation.
  - Experimental data will flow into second-generation circuit design.
  - Personnel trained in the handling of NaK.
  - Procurement and integration of a liquid metal cleaning system to enhance operation.



Liquid metal system inside 9-ft vacuum chamber

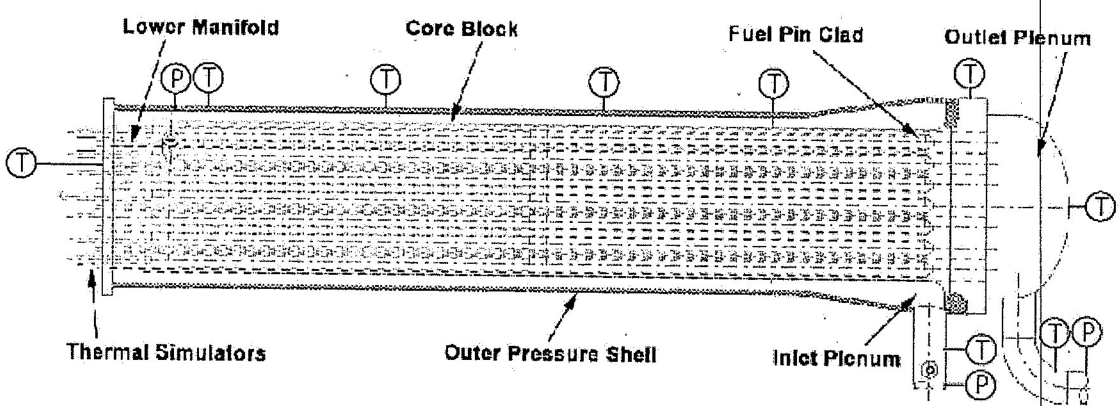
Test Configuration



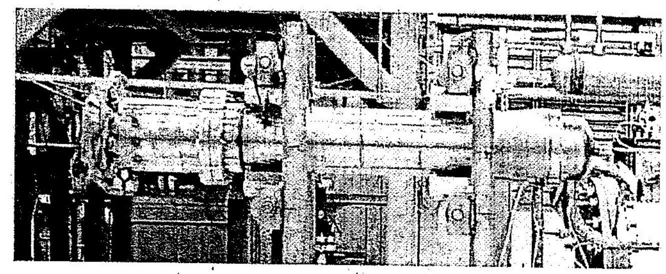


Stainless steel NaK-cooled circuit (SNaKC)

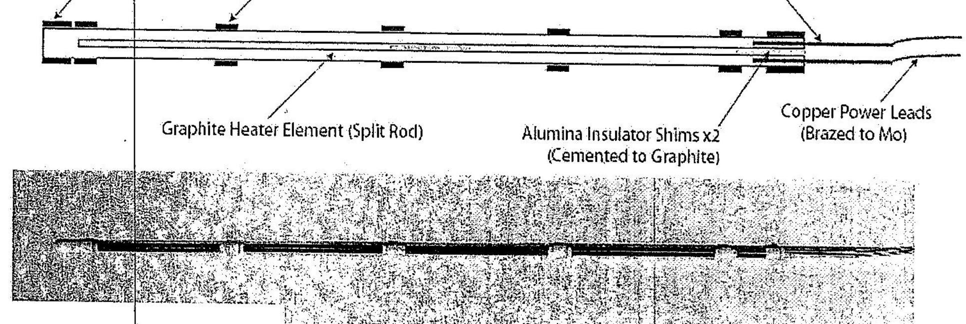
Test Configuration

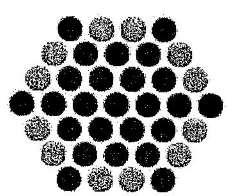


Core



- 1/3 partial core from 100 kWt LANL design study
- 37-pin assembly divided into 4 zones
- Zones allow 44 kW to be applied to thermal simulators (in total)
- 12 zones allowable at maximum (giving 180 kW input power)
- NaK can be brought up to 1000°F (537°C) maximum

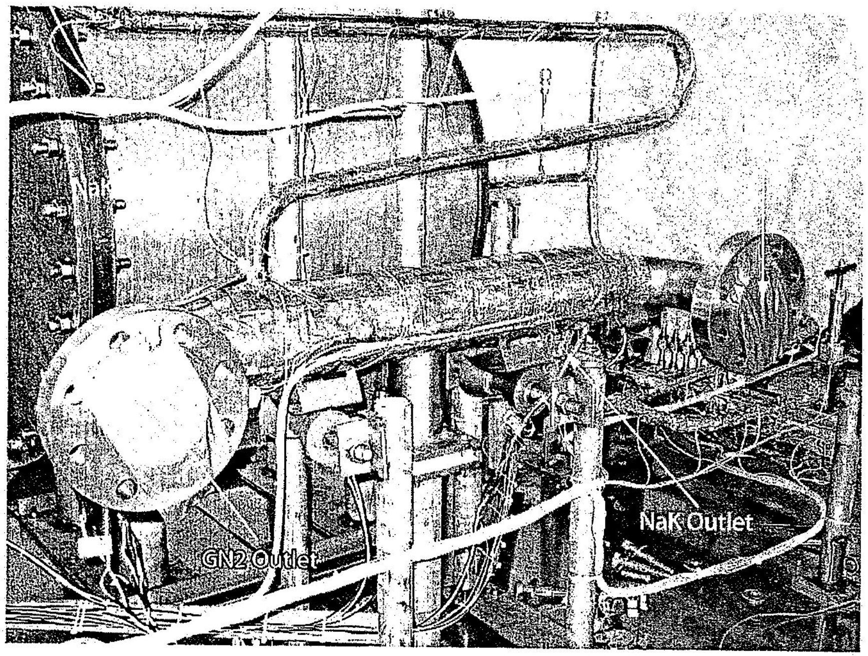




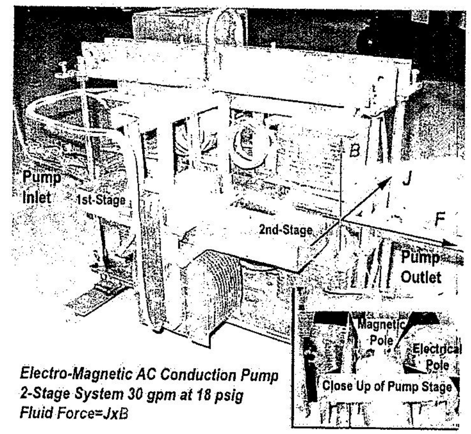
Zone 1 - 7 Heater Elements
Zone 2 - 12 Heater Elements
Zone 3 - 12 Heater Elements
Zone 4 - 6 Heater Elements

Power Zones & Thermal Simulators

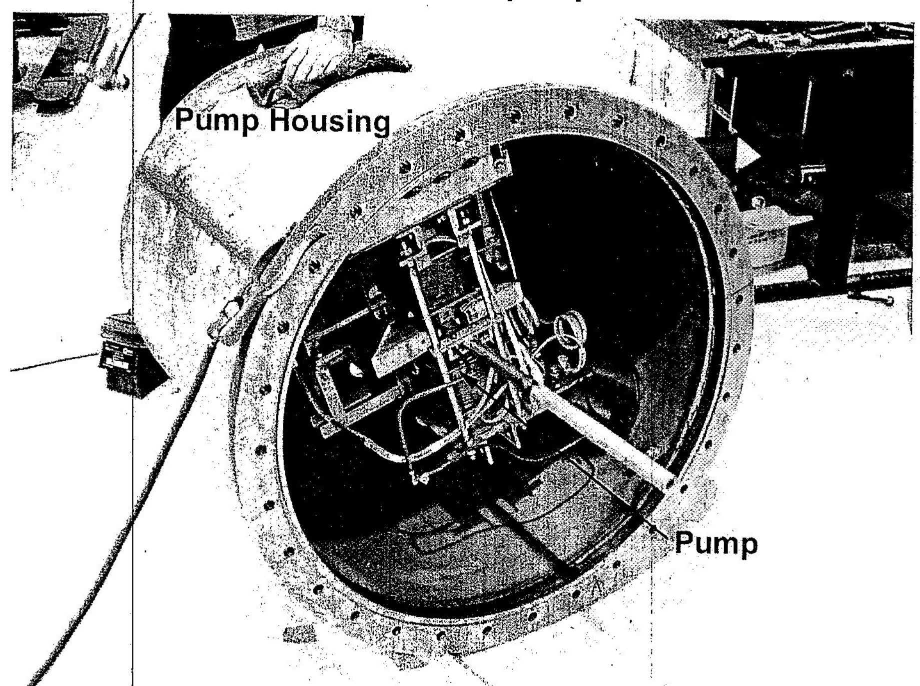
Test Configuration



Heat exchanger

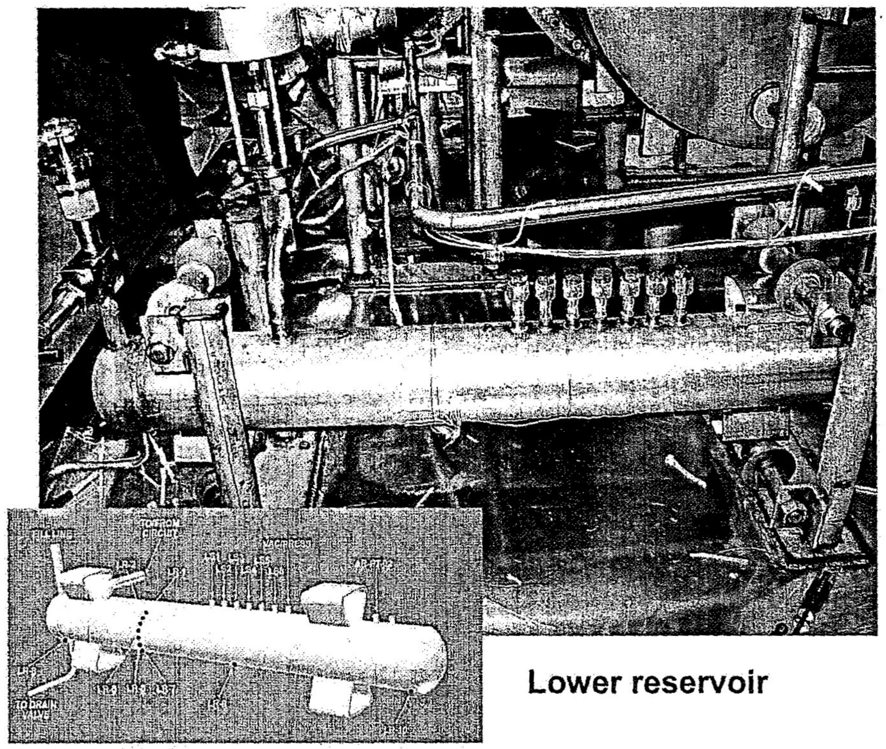


Liquid metal pump

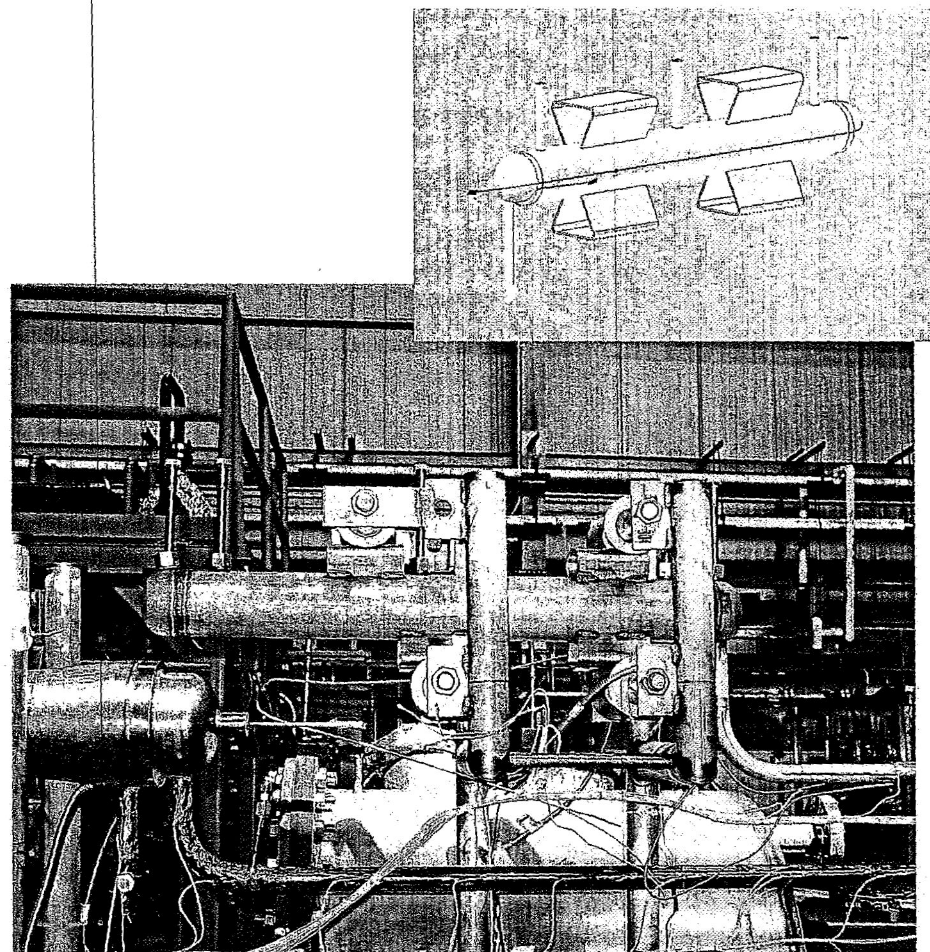


- NaK-to-GN_2 heat exchanger
  - Inlet pressure and temperature can reach 185 psia and ~400°C
- Liquid metal pump provided by CEI
  - No moving parts; operates on F=JxB principle
  - Capable of generating ~1.5 kg/s mass flow rate
  - GN_2 flows through housing for pump cooling

Test Configuration



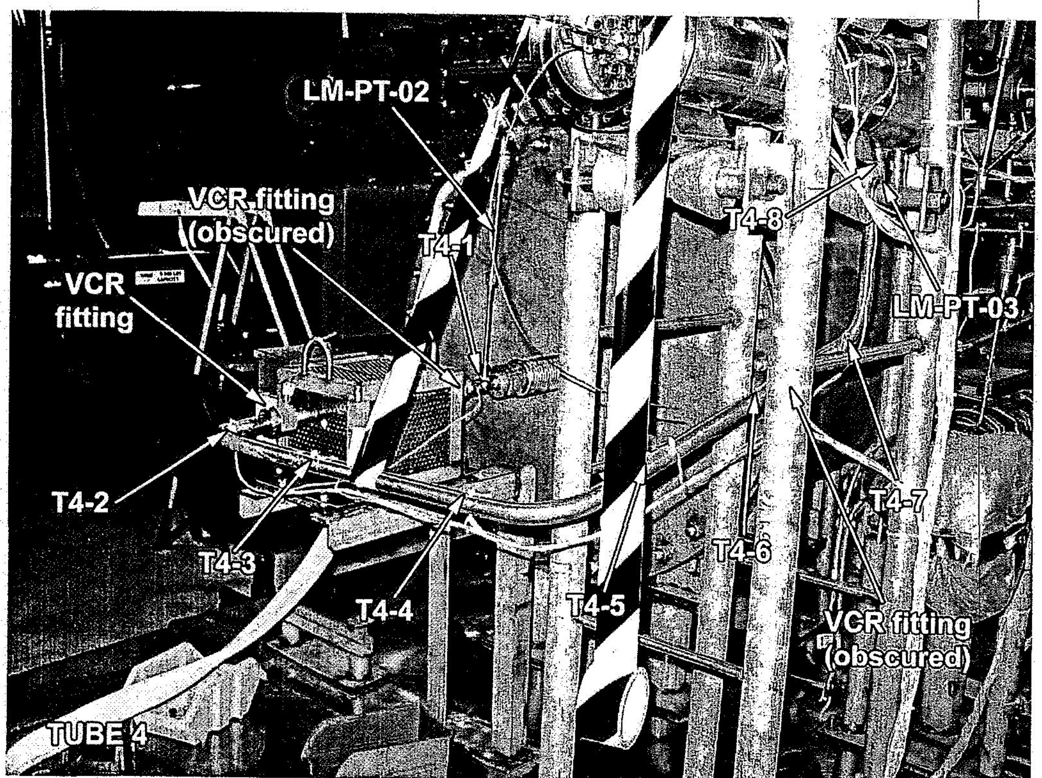
Lower reservoir



Upper reservoir

- Lower reservoir
  - Used in fill/drain operations
  - Level sensors indicate presence of NaK
  - Volume of 16928 cm^3
- Upper reservoir
  - Accomodates 17% expansion of NaK at 650°C
  - Volume of 3614 cm^3

Test Configuration

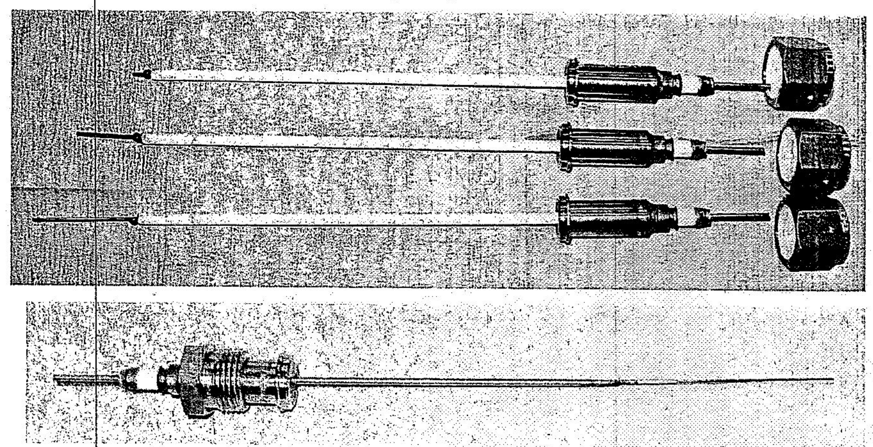


Test Section

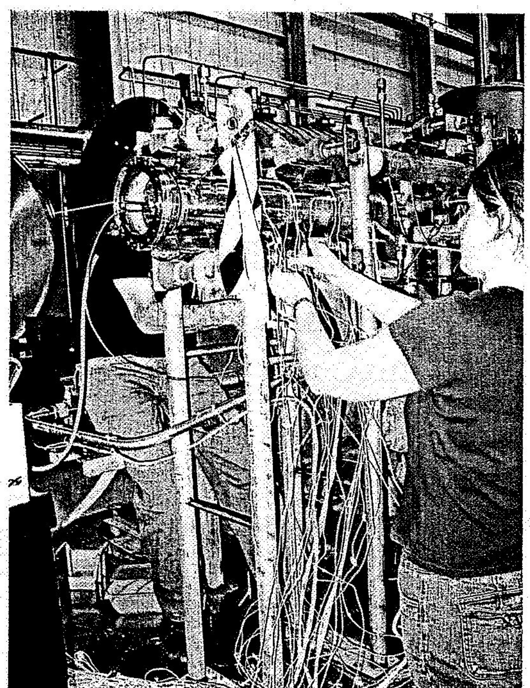
- Test section can be used for:
  - Single channel element testing
  - Liquid metal flowmeter evaluation
  - Insertion of other components into circuit (e.g. pumps)

Instrumentation

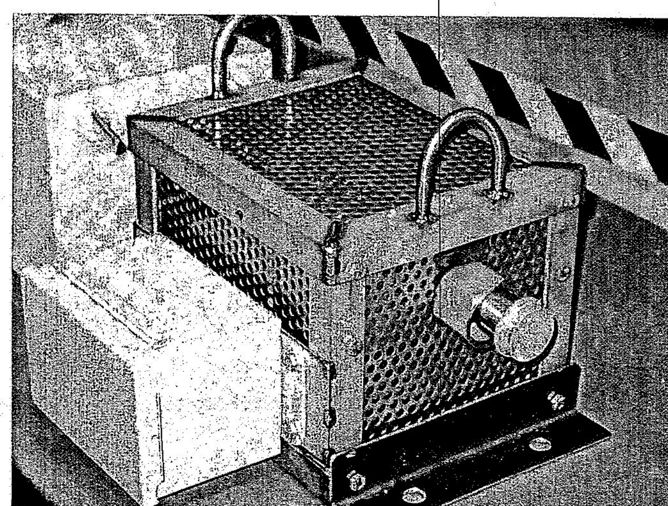
- Test article instrumentation:
  - ~75 type-K thermocouples
  - 8 pressure measurements
  - 9 level sensors (6 on LR, 3 on UR)
  - Liquid metal flowmeter
- Pressure, temperature, flow measurements for GN2 system
- LabVIEW used for data acquisition and control



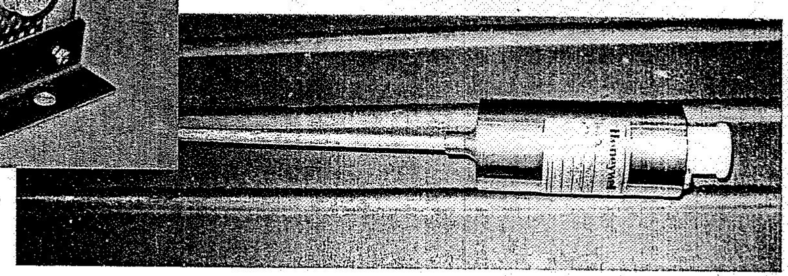
Level sensors



Thermocouples



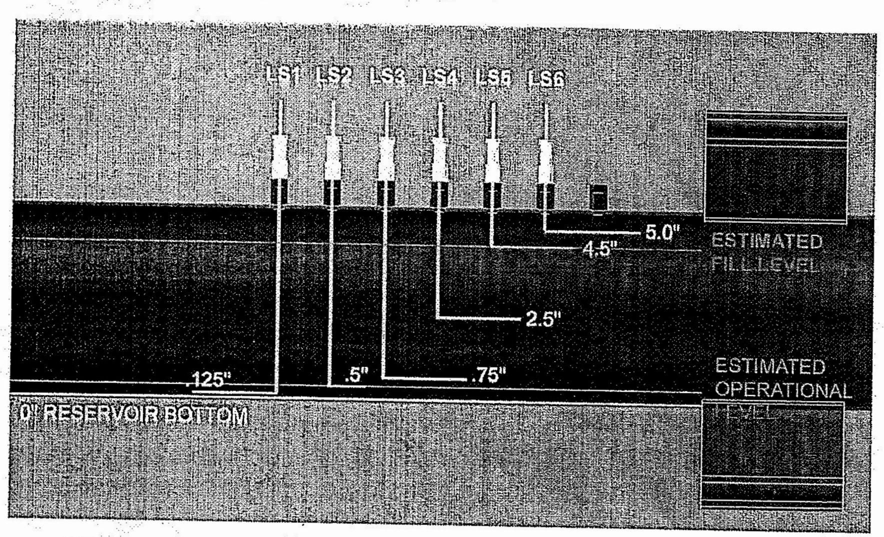
Liquid metal flowmeter

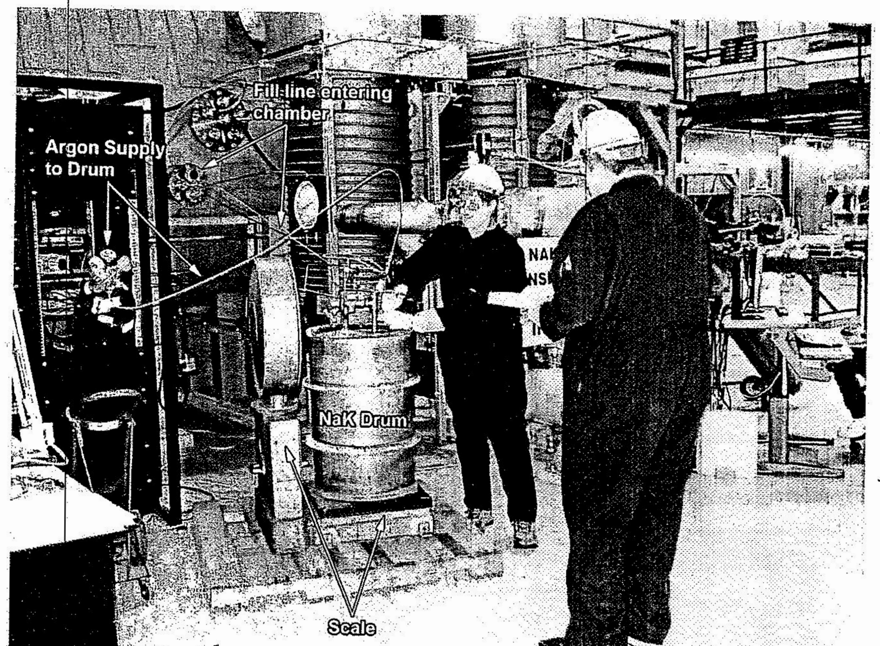


Pressure transducers

Initial Fill and Test

- Lower reservoir was filled to a height of 4.5" above the bottom of the reservoir
- Corresponds to ~15.3 L (~29.3 lbs) of NaK
- First Test
  - Applied a maximum of 13.7 kW to the core
  - Reached a temperature of 431°C (~700 K)
  - Reached a maximum NaK flow rate of 12.8 GPM (0.66 kg/sec)
  - Heat exchanger was not used





First fill of SNaKC

Testing

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
	550°C	4	2	3	1
	577°C	3	1	4	2

- Pump is reportedly inefficient at temperatures less than ~800°F (427°C)
- Pump behavior for NaK-56 at 1060°F (571°C) provided by pump manufacturer
- Test a variety of pump power settings over a range of temperatures
- Tested ranges may be varied as needed

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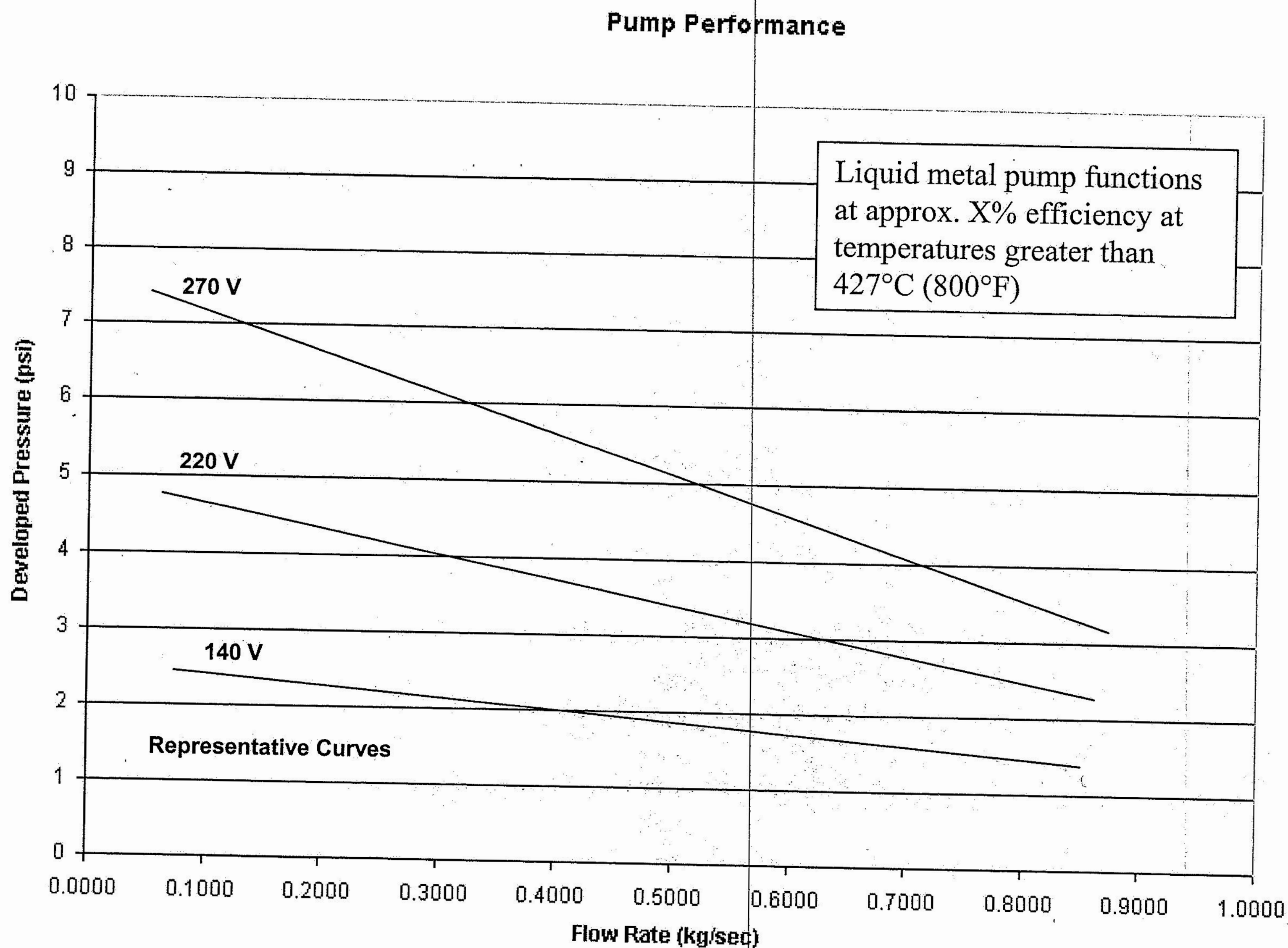
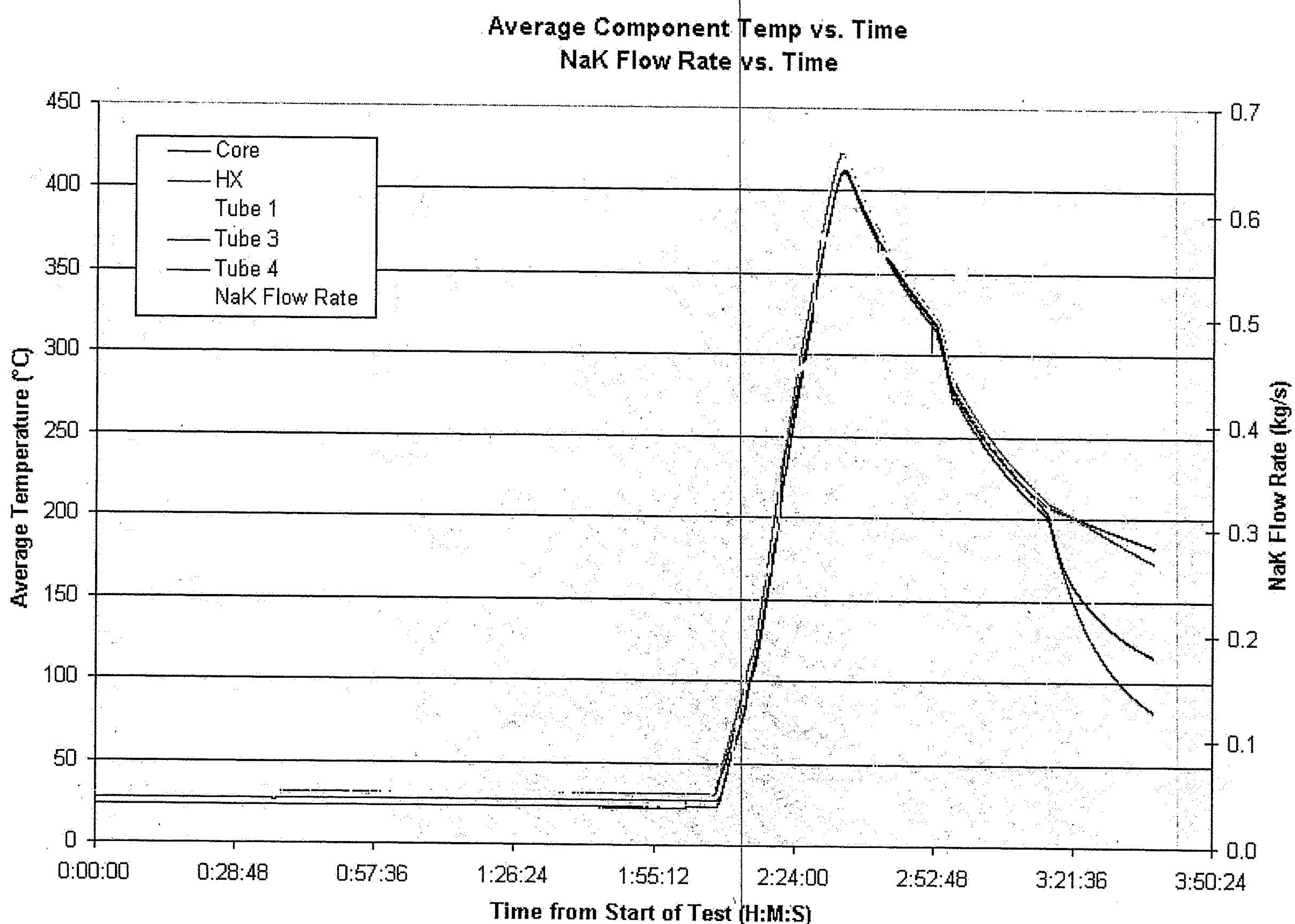
Test Results



Test Results



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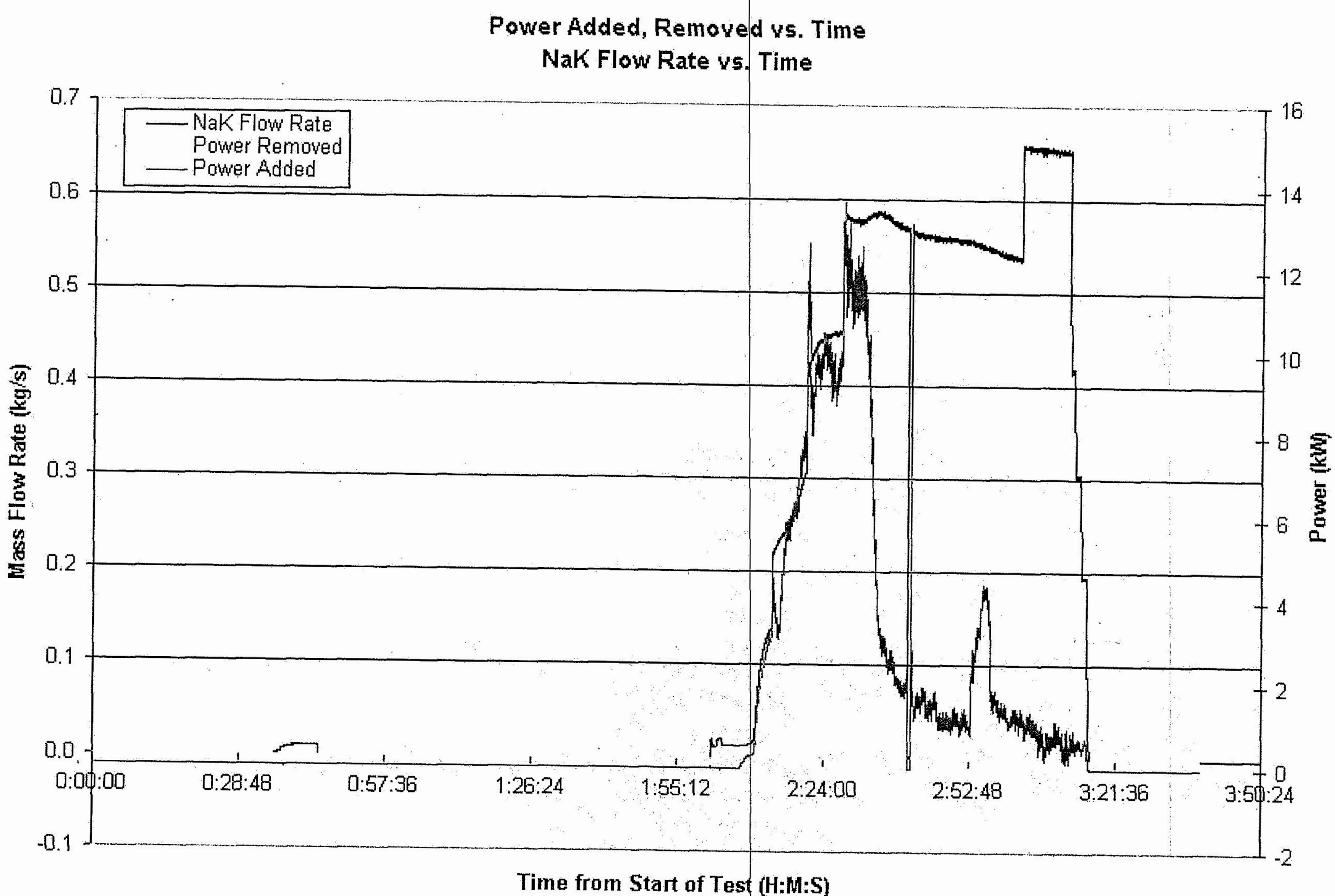
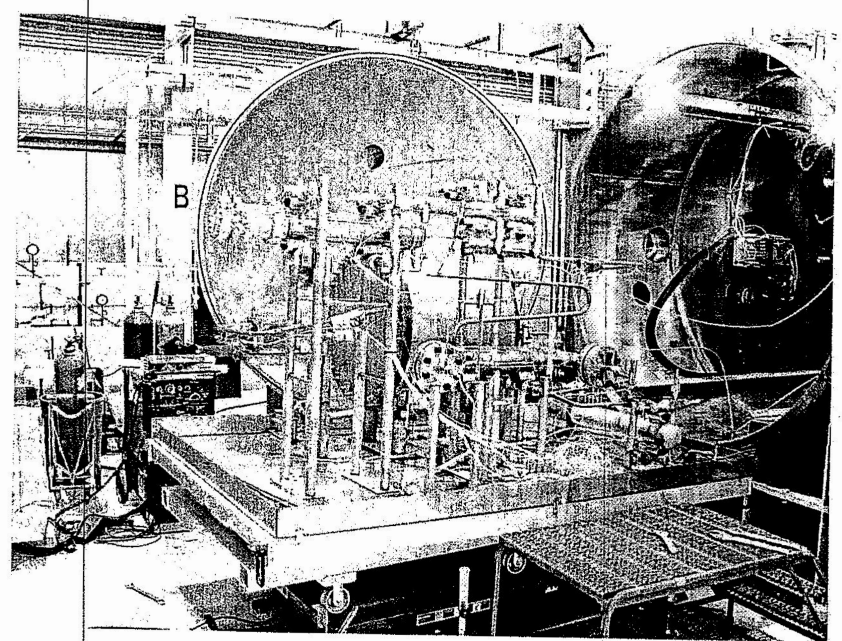


Summary

- Test article has been filled and NaK can be moved to and from the lower reservoir
- All components and instrumentation are functioning well
- Test article has been brought up to a maximum of 430°C (700 K)
- Flow rates of 12.8 GPM have been reached
- Liquid metal pump operates at X% efficiency above 427°C (800°F)
- Personnel have been trained to properly handle NaK
- Many lessons learned regarding the filling and draining of the circuit, NaK flow, changing out of components, and use of instrumentation



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Acknowledgments

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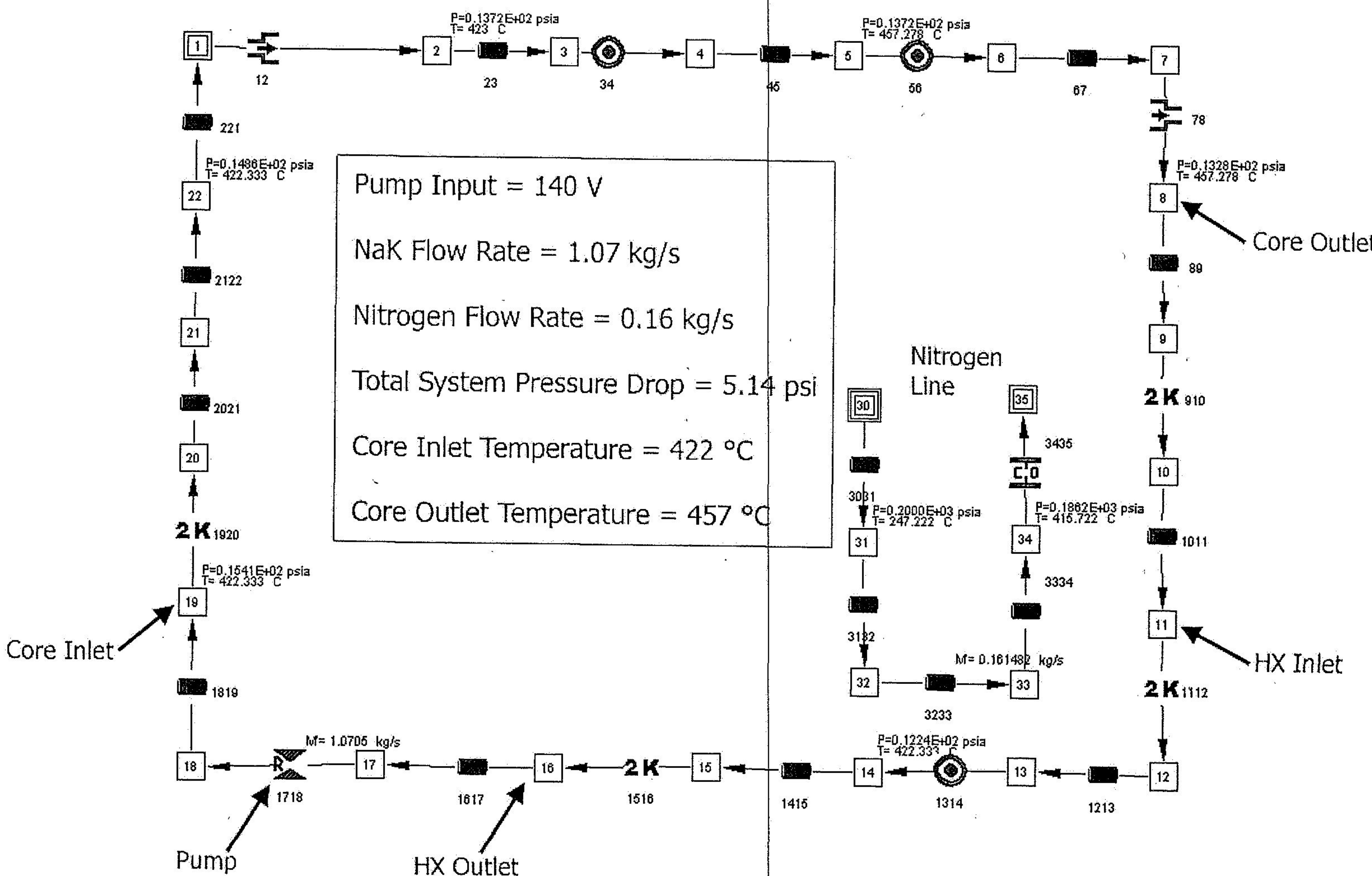
BACKUP CHARTS

Simulation



GFSSP model of SNaKC

NaK Handling Training

- Training sessions conducted by Creative Engineers, Inc.: at MSFC and at CEI facility in York, PA (CEI performed clean-up at Y-12)
- Activities:
  - Observing NaK in argon gas and in air
  - Stirring exposed NaK
  - Wiping up small spills
  - Cleaning pipe fittings
  - Burning NaK in air
  - Exposing NaK to large quantities of water
- ER24 has previous alkali metal experience (sodium purification, filling of sodium heat pipes, SAFE-30, SAFE-100A)