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Design, Fabrication and Integration of a NaK-Cooled Circuit

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Abstract – *The Early Flight Fission Test Facilities (EFF-TF) team has been tasked by the NASA Marshall Space Flight Center Nuclear Systems Office to design, fabricate, and test an actively pumped alkali metal flow circuit. The system, which was originally designed for use with a eutectic mixture of sodium potassium (NaK), was redesigned to for use with lithium. Due to a shift in focus, it is once again being prepared for use with NaK. Changes made to the actively pumped, high temperature circuit include the replacement of the expansion reservoir, addition of remotely operated valves, and modification of the support table. Basic circuit components include: reactor segment, NaK to gas heat exchanger, electromagnetic (EM) liquid metal pump, load/drain reservoir, expansion reservoir, instrumentation, and a spill reservoir. A 37-pin partial-array core (pin and flow path dimensions are the same as those in a full design) was selected for fabrication and test. This paper summarizes the integration and preparations for the fill of the pumped liquid metal NaK flow circuit.*

I. INTRODUCTION

To expand the multi-mission technology base related to the use of alkali metal systems for potential surface power application, an effort was launched within the Early Flight Fission- Test Facilities (EFF-TF) team to design, fabricate and test a pumped alkali metal (NaK) flow circuit. A year-long collaboration with Naval Reactors Prime Contractor Team (NRPCT) resulted in a shift to lithium as the heat transport mechanism. Once this collaboration ended, the system was reassessed and NaK was again selected for use in the circuit. Through all these shifts, three of the circuit elements have never changed: the electromagnetic pump, heat exchanger, and core. The circuit is comprised of these three elements along with an expansion reservoir, a lower containment reservoir, instrumentation and test section.

II. DESIGN CHANGE TO NAK

Liquid metals are an attractive choice for space reactor systems as a heat transfer medium due to their high thermal conductivities. NaK and lithium are two such metals, but NaK exhibits several characteristics that resulted in its selection over lithium. NaK-78 is a eutectic mixture of 22% sodium and 78% potassium by weight. It has a melting point of -12.6°C and a boiling point of 785°C, making it a liquid at room temperature. This melting point provides a clear benefit for fill and draining operations; lithium is solid at room temperature and must be melted before it can be pumped through a circuit. NaK has good compatibility with stainless steel over the temperature range to be tested (650°C maximum). This is an advantage over lithium, which is much more corrosive to stainless steel over this temperature range. NaK also has a demonstrated service history for use in space reactor systems, which include SNAP-10A, TOPAZ I & II, and RORSAT series. One notable disadvantage of NaK lies in its volatility. It reacts when exposed to oxygen, resulting in the formation of potassium oxide, potassium peroxide and potassium superoxide, which create a crust on the surface of the NaK. Hydrogen is released when NaK is exposed to water, and the heat of reaction causes it to burn.

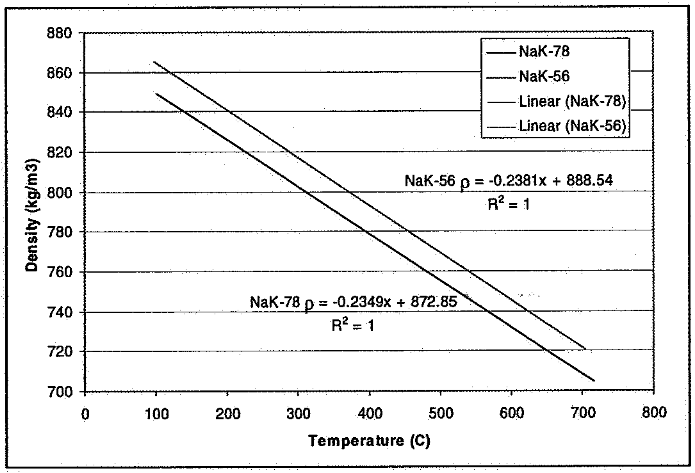

Figure 1. Thermal expansion of NaK.[1]

Another significant difference between NaK-78 and lithium lies in their relative thermal expansions. At 650°C NaK will have expanded 17% over its room temperature volume. By comparison, lithium will expand only 4% over this temperature range. Because certain components of the circuit were built for the lesser expansion rate of lithium – namely, the upper reservoir – some redesign and replacement of components was necessary to contain the greater expansion of NaK.

III. LIQUID METAL CORE DESIGN

The circuit was designed around the core, the geometry of which is based on a 100-kWt study performed by the Los Alamos National Laboratory[2]. The coolant enters the core through an annular inlet plenum that directs it into a circumferential flow passage formed between the outer shell and core block. The flow traverses this passage over the length of the core and exits into the lower manifold. This manifold distributes the coolant for a return trip to the top of the core via annular gaps formed between the fuel pin clad and core block. At the top of the core an outlet plenum collects the heated NaK. Figure 2 illustrates both the perimeter and annular fuel pin flow paths.

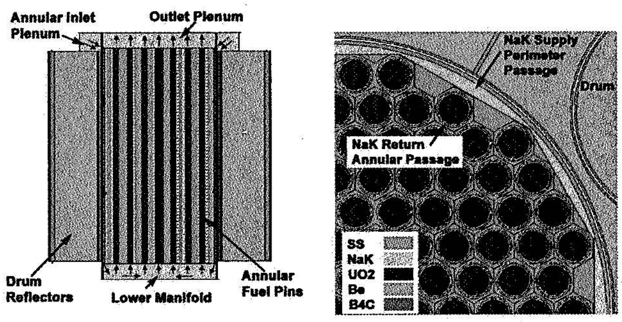

Figure 2. General core flow loop with end view.

In order to simplify the fabrication, integration and testing of the hardware, the reflector drums and shields located beyond the outer pressure shell have been eliminated. In addition, a partial array of the core geometry has been employed. A subset of the central three rings (37 fuel pins) results in a 1/3-power version of the full assembly, or 30 kW total. These reductions significantly impact the overall cost and complexity of the system. Only one electromagnetic pump is required as opposed to two, the required size of the heat exchanger and related plumbing is reduced, and fewer thermal simulators (heaters) are needed. Thermal simulators take the place of nuclear fuel in the SNaKC; all testing done at the EFF-TF is non-nuclear. These heat sources are discussed in greater detail in section IV.E.

IV. SNAKC LAYOUT

The flow diagram illustrated in Figure 3 identifies the key system elements of the SNaKC. The complete system is mounted on a tilt table which in turn is inserted into a 9-ft vacuum chamber. Instrumentation, power connections for the pump and heaters, pump cooling, valve control power, and a gaseous nitrogen closed cycle coolant loop interface with the chamber. No NaK is routed outside of the chamber. The circuit is all-welded save for a few strategic locations to attach instrumentation such as the liquid level sensors, pressure transducers, and test section connection/disconnection points. These connections are all made with VCR fittings. All components and tubing have been proof pressure tested to greater than 300 psi and leak checked using gaseous helium to better than 10^{-9} SCCM to minimize the potential for leaks. High temperature valves (remote operated where needed) are used at the lower reservoir and on the spill tank. Instrumentation measurements are made at key locations including the core, heat exchanger, reservoir and pump as well as at necessary points throughout the circuit. All components are constructed from stainless steel, primarily 316, with the exception of the level sensors. The ceramic portions of the sensors do not come into direct contact with the NaK.

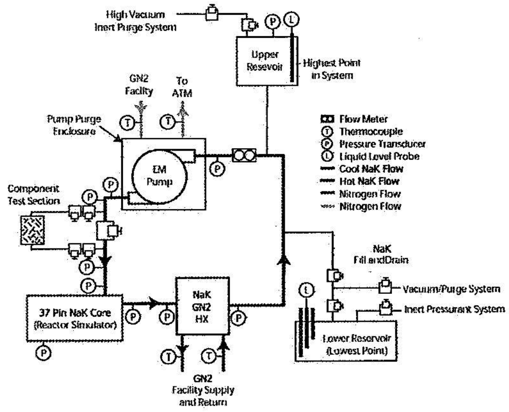

Figure 3. Simplified SNaKC flow schematic.

The as-built test circuit is shown in Figures 4 and 5. The overall layout of components and tubing was configured to provide sufficient flexibility without the use of expansion bellows in the circuit. Bellows were avoided since 1) they are a thin walled component susceptible to mechanical damage and 2) the convolutes can retain residual liquid metal, making draining and cleanup more difficult. Additionally, butt-welds were used wherever possible to eliminate possible cavities in which NaK and impurities could be trapped. The flow circuit was designed for use on a tilt table, providing a "low spot" to utilize gravity to route the NaK to the lower reservoir. In the smaller diameter tube sections, such as in the pressure transducer standoffs, a purge of high purity argon was envisioned to overcome the surface tension of the NaK and to purge the lines of the liquid metal. In general, major flow components are laid out to limit pressure drop (large flow areas) so as to maximize flow rate and to minimize pump power consumption. Subsequent sections will describe the major system components in more detail.

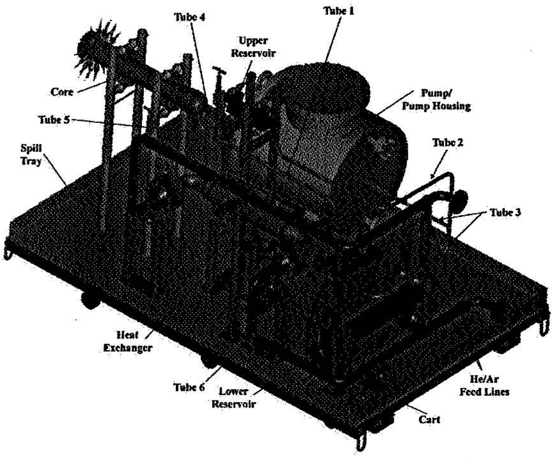

Figure 4. Liquid metal test circuit as designed.

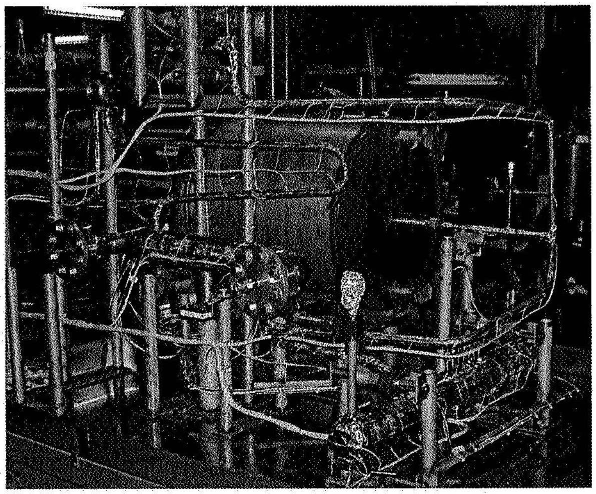

Figure 5. Liquid metal circuit as built.

Since the circuit is being modified to hold NaK, the final test circuit will be nearly identical to that shown in Figure 5 with only a few minor changes. First, a larger upper reservoir is being manufactured. This is necessary due to the greater expansion of NaK at temperature as compared to lithium. Second, a spill tank is being added to limit personnel exposure to NaK should a spill occur. The circuit will be operated in a vacuum, but the vacuum will eventually have to be broken in order to access the system. In this circumstance, any loose NaK would react with air and water vapor. The spill tank will be attached beneath the spill tray, at the edge in front of the lower reservoir. A drain will be added to allow spilled NaK to flow into this tank, located at the low point of the system. Steel "wedges" will be welded to the spill tray to ensure that the NaK flows to the drain and does not collect in the corners of the spill tray.

The volume of each major component and the overall plumbing is listed in Table 1. The total system volume is estimated at 14.6 liters, based on CAD models of the as-built circuit and the newly redesigned upper reservoir. This volume was validated through manual measurements of the lengths of tubing and inspection of the fabrication drawings. At 600°C, the NaK in the circuit will expand to fill approximately 16.9 liters of volume. The lower reservoir has sufficient volume to contain all the NaK at this temperature.

TABLE I

System Volume Breakdown

Component	**Volume (cm^3)**
Core Assembly	5424
Heat Exchanger	5440
Tubing/Pump	3736
Upper Reservoir (Old)	*1049*
Upper Reservoir (New)	3583
Total	**18183**
Lower Reservoir	16928
Spill Tank	19550

IV.A. Instrumentation

The circuit has been heavily instrumented with type-K thermocouples (TCs) that are spot-welded directly to the stainless steel. The TC wire, manufactured by Omega (HH-K-24-SLE), is a high temperature, glass-jacketed 24 gauge wire capable of operation at up to 704°C. TCs are located approximately every six inches along the lengths of tubing and in distributed patterns over the remaining components. These diagnostics monitor circuit temperature distribution and help provide system diagnosis. Additional TCs are placed on system components to provide backup to other instrumentation systems, such as level measurement or trace heater operational temperature.

There are ten locations for pressure transducers on the circuit: at the inlet and outlet of the pump, core, and heat exchanger, two on the core, one on the upper reservoir and one on the lower reservoir. The pressure transducers selected for this circuit were manufactured by Honeywell Sensotec, model TJE. Eight cover a pressure range of 0-75 psia while the others cover a range of 0-50 psia. All wetted parts are stainless steel and must remain at 100°C or below. A calculation was performed to determine the required standoff length to keep the transducers cool enough to operate reliably. The results show that if the main flow path has an operating temperature of 650°C, a standoff of 9.9" is required.

Level measurement was needed in two locations on the circuit: on the upper reservoir and on the lower reservoir. Shown in Figure 6, these are 5 kV, 30 A power feed-throughs that terminate in weld lips that are welded to a VCR fitting. This is then mated to a VCR fitting on the upper and lower reservoirs. The level sensor works by completing a circuit when the level of the NaK comes in contact with the stainless steel pin of the feed-through.

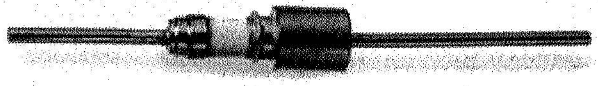

Figure 6. Level sensor.

Flow measurement will be measured in two ways. The first method is to use the heat exchanger to estimate flow from the relationship:

$$Q = \dot{m} C_p \Delta T , \tag{1}$$

where in a reasonably well insulated heat exchanger the energy coming in will be equal to that removed:

$$Q_{NaK} = Q_{Nitrogen} . \tag{2}$$

The inlet and outlet temperature of the gas and the gas flow rate are measured, and the specific heat is known for the gas. Therefore, the NaK mass flow rate can be calculated from Eq. (3):

$$\dot{m}_{NaK} = \frac{\dot{m}_N C_{p,N} \Delta T_N}{C_{p,NaK} \Delta T_{NaK}} . \tag{3}$$

The second method is to construct a flow meter using a permanent magnet to measure the current induced in a wire, which can be correlated to flow rate. The most difficult part of any flow measurement is the calibration of the device. It is hoped that these two methods will agree and corroborate each other.

IV.B. Trace Heaters and Insulation

Trace heaters are placed on nearly all circuit components and tubing such that the entire system can be heated to approximately 525°C (without the use of the thermal simulators and core). They are Watlow brand, stainless steel sheathed, 1/8" diameter, 240 V AC resistance heaters capable of continuous operation at temperatures up to 650°C with intermittent operating periods achieving up to 815°C. These heaters were cold formed to fit as snugly as possible along all sections of tubing and all major components except the core. An attempt was made to provide two trace heaters for each section being heated and to make logical sections for control of thermal input into the system.

Trace heaters are vitally important items when lithium is the heat transfer agent, as it is solid at room temperature. NaK is liquid at room temperature, so freeze/thaw will not be an issue. However, the trace heaters can still prove to be useful. They can be used prior to the NaK loading to outgas the tubing and other components by performing high temperature vacuum bake out. During this interval the temperature of all wetted components must be raised in excess of the nominal operating temperature of 600°C (expected during testing) to release absorbed water and other condensables from the metal. The system components that are lined with trace heaters are wrapped in copper foil to distribute the heat generated over the entire surface of the component. Multi-layer insulation (MLI) will be placed on top of the copper foil to prevent heat losses by radiation; however, should excessive temperature drops still be observed around the circuit, the trace heaters can be used to add power to the system where needed.

IV.C. Tilt Tray and Spill Tank

A 3 m by 2 m tilt table was fabricated from aluminum structural members and plating. It can be tilted from a level, horizontal position to an angle of five degrees. The two table support rails are equipped with six rollers, two large hinges, and four intermediate supports (to distribute weight). The support table holds all components for the circuit. It is also equipped with a stainless steel spill tray (0.1" thick) that covers its entire surface. This tray has a 13 cm high lip around its boundary, which is more than sufficient to contain all system NaK should it leak out while the table is tilted at the maximum angle. The spill tank is modeled after the shape of the lower reservoir. It has a volume of 19550 cm^3, which is sufficient to hold the total system NaK at 600°C. It is fitted with two remote operated valves: one on a ½" tube for venting, and another that closes off the 1" drain.

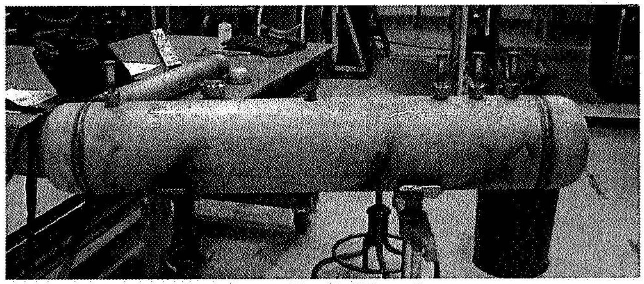

Figure 7. Spill tank.

IV.D. Core

The horizontal orientation of the core assembly simplifies heater installation. Sufficient table tilt is needed for complete drainage. Figure 8 provides a simplified schematic of the core block assembly. It is constructed of stainless steel 316 (all welded configuration) and inspected by a complete radiographic survey and helium leak detection (to a level of $1x10^{-9}$ std cc/sec). The complete core assembly consists of six primary components:

1) **Core Block**: a solid 6-sided stainless steel structure with 37 fuel pin holes gun drilled through the full length of the core block. The top end is flanged to provide a support for the inlet plenum. The back side is grooved to accept the outlet plenum cap.
2) **Outer Pressure Shell:** a large tubular jacket that surrounds the core block (forming the perimeter flow passage). This shell is flared at the top end (using a conical reducer) to provide the inlet plenum structure. The shell length extends below the bottom of the core block, forming the outer wall of the lower manifold.
3) **Inlet Plenum:** an annular manifold that is part of the outer pressure shell assemblies. It is equipped with a large feed line to minimize system pressure drop.
4) **Outlet Plenum:** a cap structure located on the top portion of the core block assembly. It is equipped with a large drain line to minimize system pressure drop.
5) **Lower Manifold:** formed between the lower segment of the outer pressure shell and the end of the core block. A stainless steel face plate (drilled to match the core block fuel pin pattern) seals the end of the manifold. This component receives inlet flow (from the perimeter passage) and directs it back up around the fuel pins.
6) **Fuel Pin Clad**: a tube that is seal welded to the lower manifold and extends along the core block to the outlet plenum (the plenum end of the tube is sealed). Heater elements are inserted into the open tube extending beyond the lower manifold faceplate. The outer edges of the fuel pin clad are equipped with standoffs at the center and outlet plenum end (set at 120 degree intervals) to maintain the annular flow path dimension between the core block and clad.

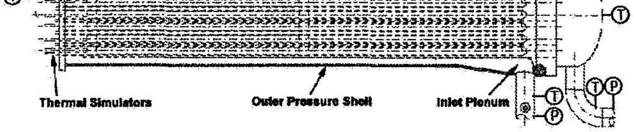

Figure 8. Core assembly.

The core block is held in place by a set of stainless steel support collars, which allow for thermal contraction and expansion during test operations. Like the rest of the circuit, it will be insulated with slip-on MLI shields to minimize heat losses during operation. Core surface temperature measurements are made by spot welding thermocouples directly to the surface. There are no thermowells inside the core block or lower manifold because they would significantly disrupt the NaK flow. One thermowell was placed in the outlet plenum. Pressure measurements will be taken on the inlet/outlet plenum lines and in the outer pressure shell just upstream of the lower plenum.

IV.E. Thermal Simulators, Power Zones, and Face Seal

The heater elements selected for this system were based on a graphite design that has been successfully used on a number of prior EFF-TF projects. A picture of these heaters is shown in Figure 9. Each element has a constant diameter of 0.775 cm with an overall length of 59.7 cm. They are equipped with alumina - insulating rings that measure 1.27 cm in length with an outside diameter of 1.067 cm. The elements are positioned approximately 4.5 cm into the core as measured from the outer surface of the lower manifold faceplate. Each heater has a resistance of approximately 0.9 ohms at room temperature and 0.5 ohms when at an operating temperature of 700°C. Fully instrumented thermal simulators (e.g. incorporating thermocouples at multiple axial locations) are being developed in parallel with SNaKC testing. If available prior to the completion of test, a small number of the core thermal simulators may be replaced with instrumented elements for additional characterization of the test article during NaK flow.

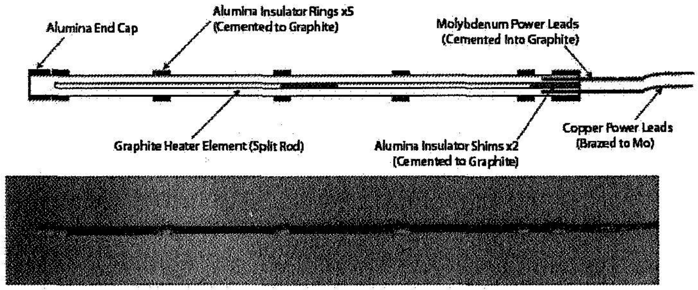

Figure 9. Thermal simulators.

Thermal simulators are assembled in zones that are connected to individual power supplies (1 power supply per zone). Each power supply is rated for 15 kW of DC power delivered via 150 V at 100 A maximum. The 37-pin core assembly is divided into three control zones, as depicted in Figure 10. The grouping of heaters in these zones (series/parallel) is laid out such that the equivalent resistance attempts to maximize the power supply output capability.

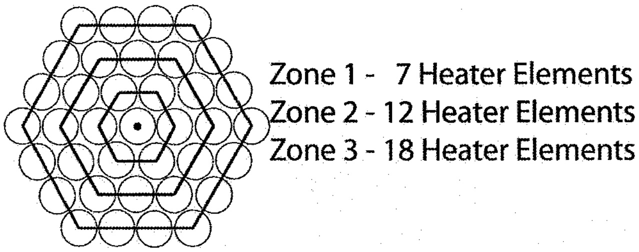

Figure 10. Power zones.

In this current zone configuration, at 700°C, a maximum of 36 kW can be transferred from the power supplies to the heaters. The central zone could be split into two parallel circuits of 4 and 3 heaters on each leg, producing an equivalent resistance of 1.2 ohms and resulting in a total available input power of 41.66 kW at 700°C. If additional power is required (to simulate transients), more power supplies could be added to create additional zones. To match the power supply load for maximum output a load of 1.5 ohms is desired; therefore, a maximum of 12 zones could be created (approximately 3 heaters per zone) resulting in a total available input power of 180 kW.

A core face seal assembly is incorporated into the 37-pin configuration to improve the thermal performance. This assembly, which is attached to the power inlet end of the core, allows for a helium environment to be established between the fuel cladding and the heater, significantly improving coupling between the heaters and core clad. This better simulates the thermal conditions in the actual core in which helium gas within the fuel pin provides excellent heat transfer across the pin. Figure 11 illustrates the core face seal concept.

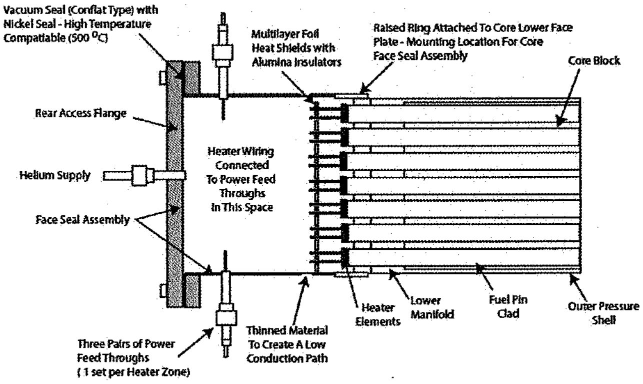

Figure 11. Core face sealing system.

IV.F. Heat Exchanger

Once the NaK is heated by the core assembly to a temperature of approximately 600°C it passes into a heat exchanger to remove up to 40 kWt. The baseline for this heat exchanger was a "battleship" or facility-style design that provides significant robustness in this initial flow circuit. It is a 0.6 m long counter-flow design with NaK confined by the outer jacket (14.1 cm outer diameter) and the secondary coolant flow (GN_2) confined by 107 tubes (0.8 cm outside diameter) that pass through the NaK flow pool. The exchanger is equipped with temperature and pressure measurements to monitor material and fluid conditions. Flow rates in excess of 0.4 kg/sec can be achieved with nitrogen inlet temperatures of 490°C. The heated exhaust gas is vented to the atmosphere.

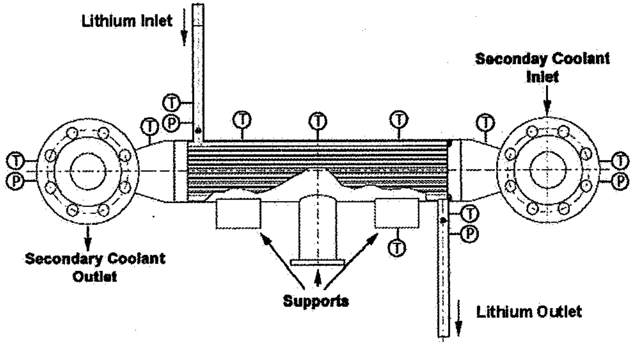

Figure 12. NaK/GN_2 heat exchanger.

IV.G. Pump

An electromagnetic pump was selected as the baseline both to maintain the integrity of the all-welded flow circuit with no moving parts and to build experience with a pump type that is applicable to a space power system. A general product search and open procurement in the commercial market resulted in a single pump submission that met the flow, temperature, and pressure requirements. This pump is a Style-VI two-stage AC conduction unit with a stainless steel 316 duct originally marketed by Mine Safety Appliance and currently offered by Creative Engineers Inc. (design dates back to the 1950's). This pump makes use of commercial windings. Figure 13 shows the pump system (protective shielding removed) before integration into the pump housing. This pump provides continuous operation at temperatures up to 816°C, with flow control from 10% to 100% (control provided by a 3-phase motor driven variable transformer).

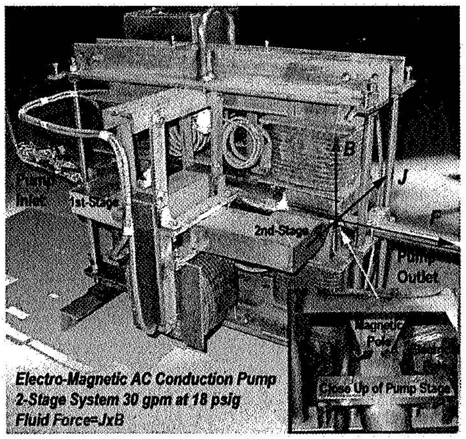

Figure 13. Pump within pump housing.

Due to heat generated by the pump and the temperature limitation of the commercial magnet coils, a stainless steel pump enclosure has been designed so that a gaseous nitrogen cooling purge can be provided to the unit while in operation at high temperature. The pump enclosure is necessary since the entire system will be placed in a vacuum chamber with pressure conditions of 10^{-5} torr or lower, eliminating natural convective cooling of the pump.

IV.H. Lower Reservoir

A lower reservoir has been placed at the lowest elevation of the system to serve as a storage vessel for both the fill and drain operations. The lower reservoir also serves as the storage tank for the NaK between tests. After the system has been baked out, the NaK will be transferred from its container into the lower reservoir via the "From Fill Pot" line using a gaseous argon purge. During fill operations, applying pressure to the top of the liquid metal will force the liquid up and into the evacuated tubes of the circuit via the To/From Circuit tube that extends to the bottom of the lower reservoir. This line contains a valve that seals the lower reservoir off from the rest of the circuit. It is remotely operated, which allows the test engineer to drain the NaK back into the lower reservoir while hot. The reservoir is equipped with thermocouples, trace heaters, a purge line and level sensors. The lengths of the level sensors decrease from LS1 to LS7; LS1, just 0.125" above the bottom of the reservoir, is the common ground.

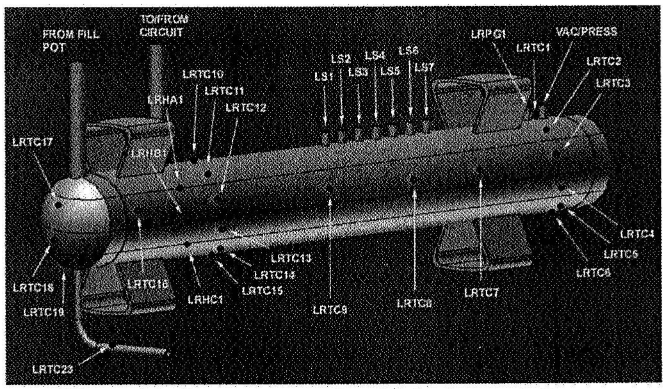

Figure 14. Lower reservoir with instrumentation.

IV.I. Upper Reservoir

The upper reservoir is required to accommodate the thermal expansion of the NaK between room temperature and the operational temperature, 600°C. This component is located at the highest point in the system. During operation, the top of the upper reservoir will be pressurized with gaseous nitrogen (at relatively low pressure) to maintain a pressure head on the system to prevent the pump from oscillating rather than circulating. This same pressurization system is also intended for use in drain procedures to drive the NaK out of the upper reservoir.

The volume of the fully filled circuit, less the lower and upper reservoirs, is 14600 cm^3. At 650°C this volume will expand by 17%; therefore, the circuit must have a total volume of 17082 cm^3 to contain all the NaK. Inclusion of the original upper reservoir only gives the circuit a total volume of 15649 cm^3. A new upper reservoir with a volume of 3583 cm^3 has been designed, which gives the circuit a total volume of 18183 cm^3 (see Table 1).

V. SYSTEM MODELING

The NaK circuit was modeled using Generalized Fluid System Simulation Program (GFSSP). This is a general-purpose program for analyzing steady-state and time-dependent flow rates, pressures, temperatures, and concentrations in a complex flow network. It is capable of modeling phase changes, compressibility, mixture thermodynamics, and external body forces such as gravity and centrifugal forces. The program contains subroutines for computing "real fluid" thermodynamic and thermophysical properties for twelve fluids.

GFSSP employs a finite volume formation of mass, momentum, and energy conservation equations in conjunction with the thermodynamic equations of state for real fluids. Mass, energy, and species conservation equations are solved at the nodes; the momentum conservation equations are solved in the branches. The system of equations describing the fluid network is solved by a hybrid numerical method that is a combination of the Newton-Raphson and successive substitution methods.

Figure 15 shows the graphical representation of the GFSSP model of the SNaKC. This model was developed while the system was being designed to hold lithium. No hardware changes have since been made that affect the actual flow path of the liquid metal, so the model was easily adapted. The working fluid characteristics in the closed loop were changed from lithium to NaK and the fluid in the open loop was changed from He to GN_2. (Lithium is reactive in the presence of nitrogen, but NaK is not.) The model includes the pump, reactor core, heat exchanger, nitrogen line and feed lines. The model calculates the pressure and temperature at each component during a steady-state operation.

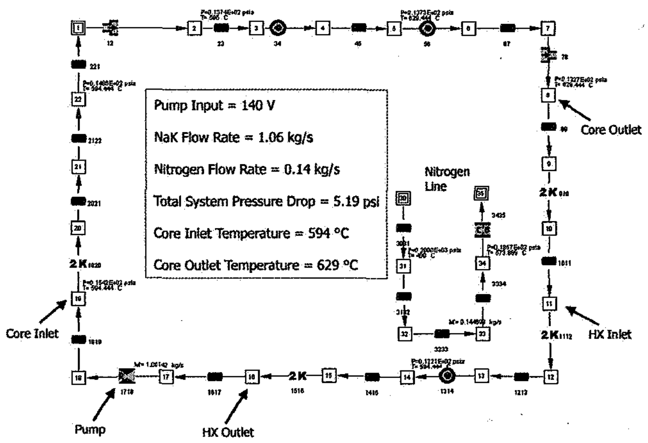

Figure 15. GFSSP model graphical representation.

The specific objective of the GFSSP circuit analysis was to calculate pressure and temperature distribution in a liquid metal cooled reactor system to assess the location and constraints of pressure transducers necessary for circuit instrumentation. Now that this objective has been achieved, the model is undergoing refinements. Currently the only reference temperature in the circuit is that of the nitrogen at the inlet of the heat exchanger. In an effort to more accurately reflect how the NaK is to be heated, a model of the thermal simulators is being built within GFSSP. In this model, heat is conducted from graphite to helium to the stainless steel clad and finally to the NaK. Inclusion of this feature will allow the user to specify a nitrogen temperature at the heat exchanger inlet and a NaK temperature (indirectly, through the graphite temperature).

The GFSSP simulation indicates that the electromagnetic pump will raise the system pressure from 10.85 psia to 16.04 psia at a flow rate of 1.06 kg/sec. The pressure drop in the core is 2.15 psi and the pressure drop across the heat exchanger is 1.18 psi. The temperature rises by 35°C between the core inlet and outlet (and falls by the same amount across the heat exchanger, indicating that the cyclic boundary condition is operating properly). The nitrogen inlet temperature and flow rate are 400°C and 0.14 kg/sec, respectively.

VI. TESTING AND END-OF-LIFE

During testing, a balance between the addition of heat through the core and removal of that heat through the heat exchanger will be achieved. In the SNaKC, the heat exchanger takes the place of a power conversion system. It can be thought of as a "Stirling simulator" – mimicking the function of a Stirling engine. A small Stirling engine produced by Sunpower, Inc. has been identified for possible future use in liquid metal circuit testing. At 25% efficiency, it converts 28 kWt to 7 kWe. Therefore, removing 28 kWt with the heat exchanger simulates the presence of this engine. The NaK flow rate is set by the voltage at which the EM pump operates. Referring to Equation 1, the power input into the system via the core can be adjusted by altering the power input to the thermal simulators, which in turn affects the temperature rise of NaK across the core. The nitrogen flow rate through the heat exchanger can be adjusted via a variable position valve (VPV). In this way the system can be balanced. A variety of NaK temperatures and flow rates will be tested; power inputs other than 28 kWt are also of interest. Regardless, the NaK will be kept at or below a temperature of 650°C.

Before the circuit can be filled and tested, end-of-life considerations must be made. When testing has been completed, the NaK will be drained into the lower reservoir. The tilt table will help ensure that no pockets of NaK remain within the system components; however, the inner surfaces of all wetted components will remain wetted. A contract is being put into place with Creative Engineers, Inc. to design, build and deliver to the EFF-TF a system that will "steam clean" the interior of the SNaKC. This system will flush steam through the circuit, resulting in the production of hydrogen, potassium hydroxide and sodium hydroxide. The engineers at Creative Engineers, Inc. have long years of experience in working with alkali metals and have built other steam cleaning systems in the past.

VII. CONCLUSIONS

The Stainless NaK Circuit is rapidly approaching test readiness. The spill tank and new upper reservoir are in various stages of completion, the spill tray is being modified, and preparations for fill are being made. Currently the project is on track for filling and beginning testing in early May of 2006.

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