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~CNLM-5732
DESIGN NO. 3 OF SNAP-50/SPUR
REACTOR TEST SYSTEMS

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CNLM-5732
DESIGN NO. 3 OF SNAP-50/SPUR
REACTOR TEST SYSTEMS

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PRATT & WHITNEY AIRCRAFT
DEPENDABLE ENGINES

Issued
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I. INTRODUCTION

Approved By: 
R. W. Kelly

June 10, 1964

R. W. Kelly
I. INTRODUCTION

This document presents the initial definition of an 8 Mwt, SNAP-50 Reactor Test and is intended to provide guidance to the Architect/Engineer in evaluating and costing various Nuclear Test Facility design concepts. The information is based on preliminary studies; and, consequently, the configuration and component sizes have not been firmly established. Where the Nuclear Test Facility design concept will be affected, however, conservative estimates of reactor test component sizes, envelopes, and requirements are presented so that facility design studies can proceed.

The objectives of the 8 Mwt SNAP-50 Reactor Test are:

1. To demonstrate the feasibility of a 8 Mwt, 2000F, lithium-cooled reactor concept.
2. To ascertain operational and control characteristics of the reactor by such techniques as, a Fuel Loading Experiment, and reactor transfer function determinations by means of a pile power oscillator.
3. To demonstrate endurance capability of the reactor and associated components.

To establish these objectives, the following test guidelines have been formulated:

1. Reactor design power - 8 Mwt
2. Reactor coolant temperatures - 2000F/1900F
3. Design life - 10,000 hours reactor full power operation
   5,000 hours preheat, afterheat removal, and miscellaneous heating conditions
4. Environment - High vacuum
5. Heat rejection (excluding reactor test items) - Proven state-of-the-art items

As part of the reactor test, it may be desirable to include a test of a SNAP-50/SPUR flight type shield. Provision for this shield test must be made in a separate vacuum chamber adjacent to the reactor test.
II. DESCRIPTION OF REACTOR, PRIMARY SYSTEM, AND SUPPORT SYSTEMS
A. REACTOR

A version of the SNAP-50 type reactor is a lithium-cooled reactor designed for a thermal power output of 8 Mw. This reactor will operate in the fast neutron energy range and utilize columbium-base alloys for the pressure vessel, core support structure, and fuel pin cladding. The reactor will be controlled by a maximum of 10 control drums in the reflector, which surrounds the core. The reflector and drums must be cooled by a separate liquid metal system utilizing a low metal with a low activation cross-section, such as potassium. Alternate concepts will be considered using the primary coolant to cool the reflector or utilizing a radiantly-cooled reflector which will reject heat directly to space.

In order to prove feasibility of this reactor concept, a test is required in which the essential features of the reactor design are retained, except that:

1) The reactor will be operated in an inverted position in which the coolant enters and exits from the top of the reactor.
2) Scram devices will be included.
3) The reflectors will radiate to the walls of a vacuum chamber rather than space.

Operation in an inverted position will provide access for assembly and disassembly and will aid in the removal of afterheat by natural convection if loss of primary coolant flow occurs.

In order to size the vacuum chamber for the reactor plus control drive motors, a maximum envelope of 50 inches diameter by 120 inches high (Fig. 1) has been defined. A minimum clearance of approximately three feet between the reactor and chamber wall should be provided to allow room for assembly of the system. Since the design is not yet firm, space should be allowed so that the control drives can be located either at the top or bottom of the vacuum chamber.

The process conditions for the reactor test are given in the table below:

<table>
<thead>
<tr>
<th>Process Conditions</th>
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</table>

| a. Reactor          |
|                     |
| Primary Coolant     |
| Max. Reactor ΔP, psi| Lithium$^7$ |
| Max. Reactor ΔT, F  | 30          |
| Max. Reactor Flow Rate, lb/sec | ~80 |
| Max. Reactor Thermal Output, Mw | ~8 |
| Max. Reactor Exit Temperature, F | 2000 |
| Vacuum Chamber Requirements | 10$^{-8}$ torr |

| b. Reflector        |
|                     |
| Reflector System Coolant | Potassium or suitable alternate |
| Max. Reflector ΔP, psi  | 5 |
| Max. Reflector ΔT, F    | 100 |
| Max. Reflector Flow Rate, lb/sec | ~35 (based on potassium) |
| Max. Reflector Heat Rejection, Kw | 400 |
| Max. Reflector Exit Temp, F | ~1000 |
FIG 1
8 MW REACTOR ENVELOPE

50"

CONTROL DRIVES

K OUT

120"

CONTROL DRIVE COLUMN

Li Li

REFLECTOR

HELIUM INLET

K IN
c. Afterheat Removal System

<table>
<thead>
<tr>
<th>Coolant</th>
<th>Helium</th>
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<tbody>
<tr>
<td>Flow Rate, lb/hr</td>
<td>~ 360</td>
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<tr>
<td>Helium ΔP in Jacket, psi</td>
<td>~ 3</td>
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<tr>
<td>Avg. Helium Exit Temperature, F</td>
<td>700</td>
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<tr>
<td>Avg. Helium Entrance Temperature, F</td>
<td>100</td>
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<tr>
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</table>

Although not an integral part of the reactor, certain items associated with the test such as pile power oscillator, neutron startup source, and neutron foil insertion thimble will be included.

The pile power oscillator is a device for mechanically inducing reactor power oscillations. A BeO segment capable of both eccentric rotation and translation will provide this function. A thimble projecting through the vacuum chamber wall will be included to provide a leak-tight extension for its drive shaft and bearings.

The neutron startup source will be either manually attached to the outer surface of the pressure vessel during final assembly of the reactor or remotely inserted through a leak-tight thimble which penetrates the vacuum chamber.

The neutron foil insertion thimble will be used to irradiate various foil materials for absolute power measurements and calibration of instrumentation during reactor startup procedure.
B. PRIMARY COOLING SYSTEM

1. General

The basic function of the primary cooling system is the removal of heat generated by nuclear fission in the reactor core. This will be accomplished by circulating lithium through four identical cooling circuits, each similar to that described for the 2 Mw Reactor Test in CNLM-5731, each consisting of a regenerator, heat exchanger and pumps. Columbium alloy will be used for all primary cooling system components and piping. A NaK Secondary Heat Rejection System will be used to transfer the heat from the primary heat exchanger to air cooled radiators. A schematic of this flow circuit is shown in Fig. 2. In addition, items such as the helium emergency afterheat removal system, vapor traps, expansion tanks, and fill and drain tanks will be included.

Two basic requirements must be met in the design of the reactor and primary test systems:

a. Protection of columbium alloy components from oxygen contamination.

b. Simulation of space conditions for radiant heat transfer.

Design and optimization of the NaK Secondary Heat Rejection System and the air cooled radiator heat dump for the 8 Mw Reactor Test will be performed as the design of the reactor test is accomplished. In order to assure that the Nuclear Test Facility is capable of accommodating the 8 Mw Reactor Test, it should be assumed that each of the four NaK loops are assembled in separate vacuum chambers, joined to the reactor vacuum chamber, and each NaK loop is cooled by an individual air radiator. This will result in an arrangement similar to the 2 Mw Reactor Test in quadruplicate. The major components are discussed in detail in the following sections.

Estimated component envelope sizes and liquid metal inventories are presented in Table I.

Table I

<table>
<thead>
<tr>
<th>Estimated Component Envelope Sizes and Liquid Metal Inventory*</th>
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<td>7) Shield Test</td>
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<td>8) Fill and Drain Tank</td>
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<td><strong>b. Inventory</strong></td>
</tr>
<tr>
<td>1) Lithium</td>
</tr>
<tr>
<td>2) NaK</td>
</tr>
<tr>
<td>3) Potassium</td>
</tr>
</tbody>
</table>

* Drawing L-102258 was used as a basis for this data
BASIC SYSTEM SCHEMATIC
(SHIELD NOT SHOWN)

TO HEAT DUMPS NO. 2, 3 AND 4

- SHIELD EXPERIMENT
- MAIN VACUUM CHAMBER
- 8 MW REACTOR
- Li TO Li REGENERATOR
- Li SURGE TANK
- NaK SURGE TANK
- AIR BLOWERS
- HEAT DUMP
- HEAT EXCHANGER Bypass
- HOT TRAP
- NaK FILL AND DRAIN TANK
- COLD TRAP AND PLUGGING INDICATOR

- CHAMBER COOLING AND HEATING
- Li FILL AND DRAIN TANK
- FREEZE PLUG VALVE
- Li PUMPS
- PUMP BLOWERS
- NaK PUMPS
- NaK FILL AND DRAIN TANK

VALVE
C  CO-EXTRUDED JOINT
The exit and entrance temperature requirements of the potassium reflector-coolant are considerably lower than the primary reactor-coolant; therefore, heat transfer media such as organics and/or water can be considered to dissipate the heat generated in the reflector. In sizing the Nuclear Test Facility, it will be necessary to provide space close to the test to accommodate potassium reflector-cooling system.

The individual items in each primary system loop are described below.

2. Regenerator

The regenerator lowers the temperature of the lithium leaving the reactor so only the reactor and regenerator are subjected to maximum system temperatures.

The 2000F lithium from the reactor is cooled to 1400F by 1300F lithium returning from the primary heat exchanger and lithium pumps. The reheated lithium enters the reactor at 1900F. The purpose of the regenerator is to lower the fluid temperature seen by the primary heat exchanger and the pumps in the lithium circuit and in the columbium-stainless steel joints in the NaK circuit.

The regenerator will be located inside the main vacuum chamber. An estimated envelope for this unit based on preliminary studies is shown in Fig. 3.

3. Primary Heat Exchanger

The heat exchanger transfers heat from the primary circuit (lithium) to the heat rejection system (NaK). The estimated envelope for a 2Mw heat exchanger based on preliminary studies is shown in Fig. 4. This heat exchanger will also be located inside the main vacuum chamber. The primary heat exchanger will be positioned a minimum of 12 feet above the reactor in order that natural convective cooling can be used to prevent core meltdown in the event of pump failure.

4. Lithium Pump

Two helical induction, electromagnetic pumps, connected in series, will serve as the primary system circulating pumps. The controls and power supply for each pump should be sufficiently redundant to prevent simultaneous failure of power to both pumps. Each pump will have sufficient capacity to circulate lithium at full power reactor operation. The pump stator will be located external to the vacuum chamber to permit replacement or repair of the stator. An envelope drawing is presented in Fig. 5.

a. Operating Environment

1) Pump Duct
   - External Pressure: $3.75 \times 10^{-7}$ torr
   - Liquid Metal: Lithium
   - Liquid Metal Temperature (max.): 1300F

2) Stator
   - Relative Humidity: 20 to 75%
   - Pressure (avg.): 14.7 psia
   - Ambient Temperature: 120F

b. Service Requirements

Electrical power must be supplied to the pump and pump controls. A three-phase 240 volt 60 cycle power supply is needed for pump power. Single-phase 120 volt 60 cycle alternating current will be needed for the control circuit. Manual operation with safety interlocks is anticipated.

A preliminary analysis indicates that an air blower will be required to supply cooling to the stator.
REGENERATOR ENVELOPE

SCALE: 1/4" = 1"

15"

45°

80"
HEAT EXCHANGER ENVELOPE

SCALE: 1/4" = 1"

15"
4" DIA
12"
45°
5. Lithium Fill and Drain System

Lithium, as supplied by the manufacturer, will be hot trapped or gettered by titanium at 1400F in a transport tank and transferred through a filter to the fill and drain tank. The primary system will then be vacuum filled through micro-metallic filters. The lithium will be dumped from the primary system into the tank through an unfiltered line. Liquid level measurement will be accomplished by "J" probe transducers in conjunction with the appropriate readout instruments (Re: "J" Probe Development, PWAC-423). The primary system will be isolated from the fill and drain system by both a pneumatically controlled valve and an air cooled freeze plug. The services required for this fill and drain system include the following:

a. Power and controls for heating the fill and drain tank to at least 1400F.
b. Temperature transducers (thermocouples) and temperature readout instruments.
c. "J" probe devices and readout instruments.
d. Vacuum pumps and associated controls are needed for liquid metal fill.
e. Purified helium (per CS-300A and 1983 specifications) at 100 psig is needed for the liquid metal cover gas system.
f. Compressed air as needed for the freeze plug and the valve operators.
g. Pressure indication for the cover gas and the air is needed to indicate system pressure level and valve position.

One fill and drain system located outside of the vacuum chambers will be adequate to serve the four primary system loops.

6. Primary System Preheat

Heat will be supplied to the primary system to bake it out, to preheat to liquid metal fill temperatures, and to permit isothermal operation at 1000F during zero power conditions.

Bakeout and preheat will be accomplished by heating the vacuum chamber system and relying on thermal radiation from vacuum chamber walls. It appears that electrical heaters on the vacuum chamber walls are the most effective means for achieving the preheat temperature; however, alternate methods should be considered.

Bakeout and preheat will be started only when a hard vacuum is achieved in the chamber. For design purposes, 72 hours is to be considered as the time required to elevate the system temperature from ambient to 1000F.

Some of the heating requirements during isothermal operation will be supplied by heat from the secondary (heat rejection) system.

7. Gas Separator

A gas separator will be needed to remove gaseous helium generated from the decay of activated lithium.

8. Lithium Expansion Tank

The expansion tank will provide space for the expansion of lithium during heating to operating conditions, and to provide a suitable location for pressurizing the primary system. "J" probe level sensors with the associated readout equipment will be used for level indication. System temperatures and operating conditions must be reviewed in order to establish the size of the tank. Purified helium (per CS-300A and 1983) will be supplied to the tank. At the present time, the location for this tank will be external to the main vacuum chamber.

One expansion tank, located external to the main vacuum chamber, will be adequate to serve the four primary system loops.
C. HEAT REJECTION SYSTEM

1. General

The 8 Mw of thermal power generated by the test reactor will be transferred by the lithium coolant of the primary system to the NaK coolant (78 percent K and 22 percent Na) of the secondary (heat rejection) system through four lithium-to-NaK heat exchangers. The secondary system provides four NaK heat rejection loops completely separate from the primary system so that the removal of heat from the primary system can be accomplished without extending the primary coolant, columbium alloy piping beyond the vacuum chamber and test cell. This heat is dumped from the NaK coolant to four separate air cooled heat exchangers. The preheat and start-up mode must be considered in the design of this heat rejection system.

This system will be constructed of type 316 stainless steel, and will have a design life of 15,000 hours, 10,000 hours of which will be at full reactor power output, and 5000 hours will be during reactor startup and shutdown. Each of the four loops must be capable of operating at a heat rejection rate up to 150 percent of the nominal capacity of 2 Mw thermal. Redundancy in the design of this system should be considered in order to protect the reactor test in the event of a component failure.

P&W drawing L-102232 shows a schematic of a single primary and secondary heat rejection system. This drawing also presents, in tabular form, the preliminary test requirements for the components of these systems. Drawing L-102258 and L-102312 show a conceptual arrangement of the reactor, a single heat rejection system and a single primary loop vacuum chamber.

It should be noted that the P&W drawings referenced in this section represent only initial design studies and will be modified as further requirements dictate.

The individual items in each heat rejection loop are described below.

2. NaK-Air Heat Exchanger

Each heat dump will consist of a NaK to air heat exchanger, constructed of type 316 stainless steel, capable of dissipating a maximum of 3 Mw of power at NaK inlet and exit conditions of 1200F and 900F, respectively. To provide for the possible failure of the air blower, two air blowers are recommended. Sufficient redundancy must be supplied in the power supply and control circuits to prevent simultaneous failure of both blowers. The blowers should be sized to carry the full load individually.

3. Columbium-Stainless Steel Interface

Coextruded columbium to stainless steel joints will be used to join the columbium primary system to the stainless steel heat rejection system. This joint is used at the tube side inlet and outlet of the lithium-NaK heat exchanger where the final welds joining the primary and secondary systems will be made. This joint will be contained within the vacuum chamber.

This same joint is to be used in the primary fill and drain system and will also be used in the primary system expansion tank if this tank is located outside the vacuum chamber.

4. NaK Pumps

Each pump must have sufficient capacity to circulate NaK at full power conditions. The control, and power supply for each pump should be sufficiently redundant to prevent simultaneous failure of power to both pumps.

For this application, electromagnetic pumps similar to those in the primary system are recommended but other alternatives may be considered if they meet the requirements for complete containment of the liquid metal.
5. NaK Fill and Drain System

Sufficient heat must be supplied to heat the fill and drain tank to 500F. A micro-metallic filter must be supplied in order to remove particulate matter during the charge cycle. A separate dump line will be supplied which bypasses the filter and therefore allows particulate matter from the system to settle in the tank during dumping. Liquid level measurement will be required which will continuously indicate the liquid metal level in the tank. A purified gas supply (per CS-300A and 1983) is required to provide pressure fill of the NaK.

One fill and drain system will be sufficient to serve the four heat rejection system loops.

6. Oxide Control

a. NaK Hot Trap and Sampling System

A NaK bypass type hot trap system to remove oxide impurities will be included in the system to inhibit corrosion. This is shown on P&W drawing 1039414, Sheets 1 and 2. In conjunction with this item, a NaK sampling station will be provided so that representative NaK samples can be taken to determine fluid purity at any time. A five percent bypass flow is required through this hot trap at all times.

b. NaK Cold Trap and Plugging Indicator

A NaK cold trap to remove oxide precipitates will also be included in the system, in conjunction with a plugging indicator. A one percent bypass flow is required through the cold trap at all times.

The use of one common Oxide Control System or a separate system in each NaK loop should be studied.

7. Heat Exchanger By-Pass

A line by-passing each lithium-NaK heat exchanger will be included along with necessary valving so that the secondary system may be operated during cleanup without exposing the columbium alloy heat exchanger. This by-pass must be designed so as to minimize diversion of flow from the heat exchanger should the by-pass valve fail in the open position.

8. Heat Rejection System Preheat

Heat must be supplied to the heat rejection system piping and components during initial bakeout prior to liquid metal filling and during isothermal operation at 1000F and zero reactor power. The bakeout temperature will be limited to 400F and is intended to remove moisture from the interior surfaces of the system. During isothermal operation and preheat of the lithium primary cooling system, it will be necessary to operate the heat rejection system at 1000F but a capability of attaining 1300F is necessary. Methods for achieving the required temperature for isothermal operation should be studied. A suggested method is flowing heated air through the radiator while circulating the NaK. A heat rate of 100F per hour should be used in determining heating requirements.

9. Expansion Tank

The function of the expansion tank is to provide space for the expansion of NaK during heating to operating conditions, and to provide a suitable location for system pressurization with purified helium per CS-300A and 1983 specification. One expansion tank, serving the four heat rejection system loops, will be adequate.

10. Valves

All liquid metal valves must be bellows sealed. Stellite 6 and 12 seat and bearing materials are recommended to prevent self-welding. Failure modes must be considered in establishing the fail safe position. Pneumatic operators are considered consistent with the operating requirements and mechanical over-rides should be included.
D. MAIN VACUUM SYSTEM

1. General

The purpose of the vacuum environment is to protect the columbium alloy reactor and its associated columbium piping and heat exchangers from contamination, and to simulate radiant heat transfer.

The main vacuum system will consist of five chambers; one containing the reactor and the other four containing the primary system loops. A connecting duct surrounding the liquid metal piping will join these chambers.

The radiation environment must be considered in selecting a location for vacuum pumps and instrumentations.

2. Requirements

a. Vacuum

A hard vacuum will be required for 15,000 hours.

1) A partial pressure for oxygen bearing and carbonaceous compounds of \(3.75 \times 10^{-7}\) torr at full reactor power conditions.

2) The main pump load in the operating range will be helium and hydrogen.

b. Preheat

The vacuum chamber walls will be used to radiate heat to the chamber contents in order to raise their temperature to 1000°F for the liquid metal fill operation.

c. Heat Load

The reactor vacuum chamber must accept a 100 Kw load generated by the reactor and the chamber walls must have an absorptivity and area that will simulate space radiant heat transfer while operating at a maximum 150°F.
E. CONTROLS AND INSTRUMENTATION

Preliminary studies of the control system for the reactor and Li-NaK-Air heat rejection system have, to date, resulted in the instrumentation and control flow diagrams given in the Reference Section.

Table III presents an estimate of the number of instrument bays (22 inches wide by 24 inches deep by 84 inches high) required for the SNAP-50 Reactor Test and is based either on existing instrumentation flow diagrams or a consideration, where possible, of similarities between this test and the LCRE.

Because of the preliminary nature of the instrumentation studies that have been conducted to date, a margin of fifty percent should be applied in sizing the facility accommodations related to space requirements for instrumentation.

In addition, an operating console will be required for the Control Area which has the approximate floor dimensions of 11 feet by 11 feet.

Table III

<table>
<thead>
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<th>System</th>
<th>Number of Bays</th>
</tr>
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<td>f. Heat Sink System</td>
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<td>g. Control System</td>
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h. Flux Monitoring System
i. Pile Oscillator System
j. Core Installation Monitoring System
k. Fuel Loading Experiment
l. Test Cell Gamma Monitoring System
m. Safety System
   Signal Conditioners and Logic Circuits
n. Shield Cooling System
o. Test Cell Cooling System
p. Area Radiation Monitoring System
q. Helium Purification System
r. Argon Purification System
s. Afterheat Removal System
t. Fission Gas Release System
u. Main Vacuum System

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* These items to be determined by Architect/Engineer.
III. REACTOR TEST PROGRAM
A. OBJECTIVE

The experimental data to be obtained from a 10,000-hour test of the 8 Mwt SNAP-50 reactor fall into three categories: feasibility, evaluation of operating characteristics and endurance capabilities. For the most part, feasibility data will be determined by test longevity and operational performance. Reactor operating characteristics will be determined during the fuel loading experiment, during special pretest physics measurements and during stability and dynamic response tests which may be performed periodically during the 10,000-hour test. Endurance capabilities will be demonstrated by operation for a prolonged period and by post-test inspection of the reactor components.

The following information will be obtained from the reactor test. Items marked with an asterisk will be evaluated by post-test inspection.

1. * Gas production in the fuel matrix and fuel pin end reflector.
2. * Fuel characteristics related to swelling, chemical compatibility and burnup limitations.
3. Reactivity changes in the core as a function of reactor lifetime.
4. Temperature coefficient changes of the core.
5. Reactivity changes for various combinations of reactor power, coolant flow rate and temperature rise, system pressure drop, etc.
7. Core pressure drop changes.
8. * Reflector structural changes (cracking, swelling, gas production, gas release, etc.).
9. Control worth of the reflectors and positional characteristics.
10. Reactor transfer functions using pile oscillator.
11. Changes in coolant exit temperature as a function of sinusoidal reactivity change caused by the pile oscillator.
13. Effect of radiation on shield bulk thermal conductivity.
B. TEST SEQUENCE

A complete description of functions pertinent to the assembly, operation, and disassembly of the reactor test experiment are contained in CNLM-5729 and are reviewed here in order to provide continuity to this report.

It is proposed that the reactor test proceed as follows:

1. Fuel Loading Experiment

The fuel loading experiment is defined as being performed in the Nuclear Test Facility.

Loading and unloading operations will be performed through the top of the vacuum chamber. Generally, individual fuel cans (dummy or loaded) will be handled by tools attached to the top of the cans. For these procedures, the reflectors will always be locked in their least reactive position during the movement of fuel or when reactivity changes are made. Access through the vacuum chamber will be provided by ports at the top, bottom and side.

Individually, each dummy fuel element assembly will be replaced with loaded assemblies. Following additions of fuel assemblies and/or after the fueled core has been completed, criticality and reactivity measurements, core compaction, reflector calibration, pile oscillator calibration and fuel loading adjustments will be conducted.

The objectives of this experiment are:

a. To assure a reactor fuel loading which is sufficient for safe operation and endurance at design power for the 10,000-hour lifetime.

b. To determine the reactivity effects of basic components and characteristics such as the pile power oscillator and compaction of the core assembly.

c. To verify the operational capabilities of the control and reactor safety system.

d. To calibrate low level nuclear instrumentation in terms of power level and to obtain supplemental data for low power calibration tests subsequent to the fuel loading experiment.

2. Assembly

The assembly of the core will be conducted with poison shrouds circumferentially enclosing the core. These shrouds will provide subcritical conditions for the core assembly for reflection from various infinite media, including water, concrete, stainless steel and lead. Therefore, the shrouds will provide a nuclear safe condition for all less extreme reflecting environments that the core may encounter during final assembly such as heavy machinery, personnel, lead shields during X-ray inspection and chambers for welding and annealing. Instrumentation to check criticality will be installed to provide continuous monitoring of criticality through all phases of the assembly.

A tentative list of the steps required for final assembly of the SNAP-50 core and pressure vessel starting with completion of the fuel loading experiment is presented in CNLM-5729.

3. Reactor Test Startup

The highest attainable vacuum should be achieved in the reactor and primary heat rejection system vacuum chambers at ambient temperature. As final verification of the integrity of the primary and secondary system, as well as for protection of the columbium alloy during preheat, low pressure, high purity helium gas will be introduced into the primary and secondary heat rejection system piping. Leaks in the piping systems within the vacuum chambers will be indicated by the detection of this helium in the vacuum system. Presence of helium will be monitored throughout the cleanup and preheat phases so that if a leak is detected prior to liquid metal fill, operation can be halted and repairs made.
Preheat of the chamber walls will be initiated and continued, maintaining the best attainable vacuum, until the vacuum chambers and their contents reach 400F. When a vacuum of approximately $10^{-6}$ torr is reached, the chamber wall temperature will be increased to 1000F at a rate limited by the impurity levels within the chambers resulting from component off-gassing. It is desirable to maintain a vacuum of approximately $10^{-8}$ torr during this preheat phase.

Liquid metal filling will proceed after the columbium alloy system has attained the preheat temperature of 1000F, first by filling the NaK system and then the lithium system. After filling, these systems will be kept at temperature.

The vacuum chamber cooling systems will be used to lower the temperature of the walls of the chambers to approximately 150F; this will be maintained for the duration of the test.

Before nuclear operation is finally achieved, a number of nuclear and systems tests and measurements will be performed. After criticality, reactor power levels and temperatures will be raised to steady state design conditions. During this phase the heat rejection system must be controlled so as not to permit conditions which exceed design requirements in either primary or secondary system components. This transition from isothermal operation to design conditions might present critical control problem due to the interaction of the systems and thermal inertia.

4. Reactor Test Operation

Once the system is operating, it will be run continuously for the scheduled 10,000 hour test period unless there is an unscheduled interruption. Interrupted operation and possible repair should be considered in the design. During this phase of the program the pile power oscillator will be activated to induce reactor power oscillation by changing reactivity by approximately two to three cents. This will permit evaluation of the reactor transfer functions.

5. Shutdown

Afterheat Removal

a. Normal

Afterheat removal subsequent to normal shutdown of the reactor will be provided by circulating the primary coolant, lithium, through the core until the power has decayed to a sufficiently low level for reactor removal to be started, probably in the order of 100 days after shutdown. To compensate for heat losses during this period, auxiliary heat from the secondary system may be used to maintain primary system temperatures above the freezing temperature of lithium.

b. Emergency

To remove reactor afterheat in the occurrence of various emergency conditions which disrupt flow only of lithium through the core, a circulating helium system will be employed. The helium will flow over the outside of pressure vessel in an annulus provided for this purpose. The heated helium will then be exhausted from this annulus at the top of the reactor directly into the vacuum chamber and recirculated through the heat dump.

6. Disassembly

Disassembly is concerned with the handling of systems components, the decontamination of these components, and post-test examination.

Following shutdown and draining of all liquid metal from the primary and secondary systems with the exceptions of undrainable pockets and the reactor core and pressure vessel, remote disassembly of the reactor and primary system will be initiated.
This disassembly will proceed as outlined in the following sequence which is presented only to convey the complex requirements involved in remote handling.

a. Flood test cell with pure argon to prevent oxidation of exposed columbium alloy surfaces when the vacuum chamber is opened, and to prevent exothermic reactions of lithium with the residual atmosphere when the reactor is severed from the primary system.

b. Open the reactor vacuum chamber. Remove reactor afterheat by flowing test cell argon through the reactor afterheat shroud.

c. Insert poison segments and reflector blocks between the reflector assembly and the reactor to prevent accidental reflection from extraneous materials or inadvertent rotation of the reflectors.

d. Tap the inlet and exit pipes of the reactor in order to ascertain completeness of the lithium drain. Drain through these taps is necessary.

e. Sever the reactor from the primary system by cutting the inlet and exit lines above the tap holes.

f. Attach pipe extensions to the severed reactor pipes to prevent lithium spillage during handling or overflow from thermal expansion of liquid lithium when the afterheat removal system is stopped.

g. Stop argon flow and lift reactor from test cell into a poison shroud which circumferentially encloses the pressure vessel (the reactor will be independently supported from the top and bottom during removal). This operation will be conducted at a time when reactor afterheat is sufficiently low to limit core temperatures to less than 1000°F.

h. Place shrouded reactor on dolly and transfer to the disassembly shop. Maintain argon atmosphere.

i. Invert the shrouded reactor (pipe openings at bottom) over a floor pan which will confine any liquid lithium which drains from the reactor pipes during the inversion.

j. Immerse the shrouded reactor in a NaK filled container in the inverted position (pipe openings at bottom). This NaK container will have a constant temperature control in the range of 400°F to 500°F. The reactor will be independently supported from the top and bottom during this operation. The rate of immersion will be controlled to minimize thermal stresses and to allow melting of the lithium, if necessary, to progress from the open ends of the pressure vessel.

k. After the reactor and NaK bath are at an isothermal condition, a hole will be cut in the top of the pressure vessel (the closed end) while holding the bottom portion partially submerged in the NaK. This hole will let the more dense NaK displace the liquid lithium in the core when the core is submerged.

l. Drain the liquid lithium from the top of the NaK container.

m. Withdraw the shrouded reactor from the NaK container and make circumferential and longitudinal cuts in the pressure vessel to remove the core.

n. With the poison shroud in position, cut the compacting bands around the core assembly and repeat the NaK procedure of step j.

o. Remove the core assembly from the NaK bath after draining the surface lithium. Machine off the support nuts to free the fuel element assemblies from the core plate. This operation will be performed in a combination poison shroud and structural basket which will restrict movement of the loosened fuel element assemblies.
Individually remove each fuel element assembly from the core assembly, insert into poison shrouds, immerse the individual assemblies into the NaK bath if necessary, and store for further disassembly and post-test inspection.

The primary and secondary systems will be dismantled, decontaminated, and selectively examined. Depending on the degree of activity and size, the decontamination and sectioning may be performed either in the disassembly cell or the Hot Laboratory. Decontamination of the primary system components will probably use the NaK flushing procedure previously described. The secondary system will probably use the steam decontaminated procedure described in CS-5001.

Following decontamination and sectioning, specific areas of the reactor, primary system components, and secondary system components will be subjected to metallographic and chemical analysis. This evaluation will be performed either in the Hot Laboratory (Building 450) or in the General Laboratory (Building 140), depending on the degree of activation.
IV. SHIELD EXPERIMENT
IV. SHIELD EXPERIMENT

1. General

The shield experiment will be conducted to determine if the flight shield will radiantly reject the heat generated by neutron and gamma radiation, and if the thermal properties of the shield will deteriorate due to swelling and cracking caused by helium production. Changes in nuclear properties due to hydrogen migration will also be measured.

The test will consist of subjecting a full scale neutron shield or segment thereof to a radiation environment where measurements such as temperature, pressure, outgassing rate, and flux will be made. The shield will be located within a vacuum chamber to simulate radiant heat transfer. The shield test chamber and its vacuum pumping system will be completely separate from the reactor test so that a shield test failure will not compromise the reactor test. Fig. 6 shows the approximate dimensions of the flight shield.

2. Requirements

a. Vacuum

A vacuum of $10^{-5}$ torr is required at test operating conditions.

b. Preheat

The vacuum system preheat and bakeout will require a chamber temperature of 500F.

c. Cooling Load

The shield vacuum chamber walls must accept a radiant heat load of 24 Kw and be maintained at 150F.
FLIGHT SHIELD ENVELOPE

6. STUB FOR GAS MONITOR

40"

60"

TEST SHIELD

INSTRUMENT BULKHEAD
V. REFERENCES
B. LAYOUTS AND DRAWINGS

1. L-102224, "Reactor & Containment Study" (classified).
2. L-102232, "Process Diagram Reactor Test Li-NaK-Air" (classified).
3. L-102251, "Test Cell Powerplant Facility".
4. L-102258, "Reactor Test Arrangement Study Li-NaK-Air 2 Mw" (classified).
5. L-102260, "300 Kwe NNST in Minimum Vacuum Tanks".
6. L-102266, "Envelope, Test Powerplant, 4 Module".
7. L-102267, "Reactor with One Power Conversion Unit".
8. L-102269, "Power Conversion Unit Arrangement Test".
9. L-102307, "Shield Test-Study" (classified).
10. L-102311, "Reactor Scram Mechanism Design Study" (classified).

*11. L-102312, "Reactor Test Arrangement Study" (classified).

12. L-102313, "Pile Oscillator Study" (classified).

13. Instrument and Control Flow Diagrams**.
   a. 1039418, "Reactor Control System" (classified).
   b. 1039417, "Primary Circuit-Flux Monitoring".
   c. 1039412, "Primary System" (classified).
   e. 1039414, "Oxide Control Station".
   f. 1039415, "Heat Sink System".
   g. 1039420, "Fuel Loading Experiment".
   h. 1039419, "Core Installation Monitoring System".
   i. 1039416, "Pile Oscillator".

*The arrangement depicted on this drawing was developed in conjunction with a heat rejection system different from the one selected, however, those portions of the drawing showing reactor, vacuum chamber, shield test, vacuum pump arrangement and gamma and neutron leakage flux is appropriate to the test design and reflects more recent work than that incorporated on drawing L-102258.

**Each of these diagrams consists of two sheets. Sheet 1 is the flow diagram and Sheet 2 is the parts list.
RESTRICTED DATA

This document contains restricted data as defined in the Atomic Energy Act of 1954. Its transmission or the disclosure of its contents in any manner to an unauthorized person is prohibited.