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SAFEGUARDS SPTF REPORT

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SNAP PRELAUNCH
TEST FACILITY
SAFEGUARDS REPORT

By
B. F. UREDA

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I. INTRODUCTION AND SUMMARY

A. INTRODUCTION

The objective of this report is to demonstrate that the activity in the SNAP 10A program to be conducted in the SNAP Prelaunch Test Facility (SPTF, Figure 1) at Vandenberg Air Force Base (VAFB) was given sufficient consideration to insure the safety of the operation. Specific consideration was given to the location and design of the facility, selection of operating equipment, limitation of operations to nonnuclear, and definition and control of operating procedures. A hazards analysis of these operations and a discussion of the postulated maximum credible accident and its consequences forms a part of this report.

The SNAP 10A program goal is to develop and demonstrate the operation of a complete nuclear power system in the space environment. These SNAP 10A Units and their related support systems will be developed and qualified at the

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Figure 1. Prelaunch Test Facility - Building 060

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Atomics International Nuclear Field Laboratory at Santa Susana (NFLSS), California. Nuclear fuel loading, criticality tests, NaK loading, nonnuclear system testing, and final reactivity adjustments will have been completed during acceptance tests prior to shipment to the SPTF. The assembly, checkout and handling operations at the SPTF will prepare the SNAP 10A Unit for integration with the Agena orbital stage vehicle on the launch pad at the Naval Missile Facility, Point Arguello (NMFPA).

Peripheral program activities, such as the shipment of the units from NFLSS to VAFB and from VAFB to the NMFPA will be reported in the shipment safeguards report, No. NAA-SR-MEMO-8147. The flight safety report, NAA-SR-7774, covering the launch pad activity analysis is referenced.

A separate operating manual presenting a SNAP 10A system description and the SPTF detailed assembly, handling and checkout procedures is being written. This report will only cover SNAP 10A Units. Other SNAP systems utilizing this facility will require an addendum to this report.

B. OPERATIONS SUMMARY

The reassembly and prelaunch test program to be conducted in the SPTF is presented in Section IV. Briefly, the facility capabilities will permit the performance of the following nonnuclear operations:

- 1) Physical inspection of the SNAP Unit, the reflector assembly, the radiation shield, and the ejectable heat shield.
- 2) Minor repairs and modifications, such as replacement of electrical connectors, amplifiers, timers.
- 3) Safe storage of SNAP Units maintaining the 12-ft minimum separation distance discussed in Appendix B.
- 4) Component, subsystem and system testing to establish flight readiness. Nuclear or thermal tests will be excluded.
- 5) Reassembly on the SNAP 10A Power Unit of the radiation shield and reflector assembly.
- 6) Mating and compatibility checks with Agena assemblies; specifically, the Agena/SNAP 10A Power Unit mating ring and the Agena nose cone fairing.

- 7) Center of gravity determination.
- 8) Fit check of the ejectable heat shield.

C. SAFEGUARDS

The SPTF is designed to maintain safety requirements established by Atomics International and the AEC. To provide for safe operations of the facility and to minimize radiological hazards, strict operational and administrative procedures will be followed. The prelaunch test program is planned so that tests or assembly operations in the facility or any accident will not allow the reactor to achieve a critical configuration. Consequently, the building design does not include containment or shielding provisions. The safeguards analysis of the operations in SPTF considers two types of accidents, nuclear and non-nuclear, with the conclusion that only nonnuclear accidents are credible. Section VI of this report contains an analysis of the safeguards incorporated in the design to prevent the occurrence of a critical configuration, showing that operation of SPTF will not constitute a hazard to operating personnel or to surrounding occupied areas outside the site area. The possible accidental hazardous conditions and consequences are summarized below:

1. Nuclear

The possibility of an accident, causing reactor criticality, is judged to be incredible because of the following considerations. No nuclear testing will be performed in SPTF. Mechanical safeguard features and controlled administrative procedures always ensure subcriticality under all accident conditions. The safeguard features which prevent reactivity insertion are:

- a) A nonreflecting shipping sleeve surrounds the reactor whenever the reflector assembly is not installed.
- b) Void filler blocks are used to fill the voids between the reactor and control drums. The void filler blocks will not be removed while the reflector assembly is installed on the SNAP Unit in the SPTF.
- c) At all times four key operated drum locking arms lock the drums in their least reactive position.
- d) Independent locking pins also prevent drum rotation (pins are squib-fired but squibs are not installed in SPTF).

- e) A reflector installation fixture mechanically controls the rate of reactivity insertion by a low ratio screw mechanism whenever the reflector assembly is installed. This fixture is capable of sequentially installing each reflector half without dismounting the fixture from the SNAP 10A power unit handling fixture. This installation is controlled by a sequence of mechanical interlocks assuring that void filler blocks and drum locking devices are always holding the drums in the OUT position.

These safeguard components are designed to provide positive assurance of a subcritical condition. Only by deliberate physical alteration of their protective features would it be possible to add enough reactivity for the reactor to become critical.

2. Non-nuclear

Potential hazards are encountered in those nonnuclear accidents involving the presence of lithium hydride, NaK, beryllium, and a limited fission product inventory resulting from criticality tests at Santa Susana. This safeguards analysis indicates the most potentially hazardous accident could result from a NaK fire. Therefore, a NaK fire in the immediate vicinity of the core is postulated as the maximum credible accident. This fire is assumed to occur after the SNAP Unit is removed from the shipping container and the reflector assembly is installed.

The maximum fission product inventory within the core at the time of arrival is the inventory remaining from the zero power critical acceptance tests (approximately 16-whr burnup) conducted at the Santa Susana Facility after allowing a decay period normally needed to prepare the power unit for shipment. The residual activity in the SPTF associated with fission products from acceptance testing will always be less than that associated with uranium. The temperature of the fire is assumed to be 1200 to 1436°F. This is not sufficiently high to cause the fuel element cladding to rupture or the beryllium reflectors to oxidize.

The temperatures to which the beryllium could conceivably be exposed in the NaK fire could not possibly result in a significant airborne release of Be or BeO.³ A similar argument holds regarding the residual fission products since the accident temperatures are too low to result in fuel element cladding rupture.

However, even if some means of mechanical rupture should occur, the maximum concentration of volatile fission product (Xe and Kr) is $3.3 \times 10^{-7} \mu\text{c/cc}$, which is less than the MPC for a 40-hr week. The maximum concentration for I^{131} is $1.14 \times 10^{-7} \mu\text{c/cc}$, which would result in a dose of about 100 mrem to the thyroid in a 30-min exposure. These values remain within the acceptable limits.

The maximum specific activity of uranium in the High Bay area due to its vapor pressure at 1436°F is a factor of over 10^4 lower than the MPC value of $1 \times 10^{-10} \mu\text{c/cc}$ for a 40-hr week in a controlled area.

D. CONCLUSION

This report establishes that all operations are adequately protected by features in the SNAP Unit design, test and handling equipment design, and building design and location. Consequently, operations in the facility do not constitute a significant safety hazard to operating personnel or to surrounding occupied areas.

II. FACILITY DESCRIPTION

A. LOCATION

The SNAP Prelaunch Test Facility is located on 13th Street, one-half mile south of New Mexico Street in the south end of the Vandenberg Air Force Base in western Santa Barbara County of Southern California. Figure 2 shows the location of the facility in relation to other buildings on the site. The remoteness of the building is particularly apparent in Figure 3. Vandenberg AFB is approximately 140 miles northwest of Los Angeles and 55 miles west-northwest of Santa Barbara. Details covering the topography, meteorological and other site conditions, together with the population density of the surrounding area, are given in Appendix A.

B. BUILDING

1. General

The entire facility is housed in a building 60 ft wide and 87 ft long. The main entrances are on the long side of the building facing to the northeast. The building is divided into two basic areas, the high bay and low bay. The high bay operations will include final SNAP Unit assembly, inspection, test and storage. The low bay area includes the office space, rest rooms, machine shop, instrument maintenance laboratory, and auxiliary equipment rooms. The exterior walls are metal siding over steel framing while the roof is steel decking with built-up roofing. The floor is a concrete slab with cable trenches in the high bay area. The building has been constructed using standard design and field practices. Special building features include positive air pressure ventilation systems, door seals, and air filters to minimize the amount of dust infiltration into the building. Other features are dust-free air conditioning in the instrument laboratory, a radiation alarm system, NaK fire protection equipment (Ref. II.C.2), and a 5-ton overhead crane in the high bay. The floor elevation is set to assure drainage away from the building under all conditions. The separating walls between the low bay and high bay areas and between the boiler and equipment room and other interior spaces are constructed of studded walls with fire-retardant gypsum wallboards. Figures 4 and 5 show the floor plan and elevation views of the building.

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Figure 2. SNAP Prelaunch Test Facility at Vandenberg AFB

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Figure 3. Remote Location of SPTF

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Figure 4. Floor Plan of the SNAP Prelaunch Test Facility

Figure 5. Elevation of the SNAP Prelaunch Test Facility

2. High Bay

The high bay, a 41- by 60-ft open area, contains the space and equipment for performing the necessary prelaunch assembly and testing operations of the assembled SNAP Unit. The space is divided into a receiving and shipping area, a shipping container storage area, and a final assembly and testing area. Approximately 65% of the usable floor area is serviced by a 5-ton capacity 3-motor overhead traveling bridge crane. The crane elevation is set to permit a vertical hook lift of 32 ft above the finished floor and clear of the bridge span members. The 3-motor-single-trolley crane is operated from the pendant control and provides the following speed ranges:

- a) Bridge travel 10 and 45 ft/min with four step increments.
- b) Trolley travel 8 and 37 ft/min with four step increments.
- c) Hoist five steps from 10 to 30 ft/min with precise inching control.
- d) A hydra-set attached to the trolley-crane hook provides control, thus eliminating any possible load-shock to the SNAP system.

Equipment access to the high bay area is made through one 14- by 20-ft vertical lift sliding steel door at the east end of the high bay. This door is hand operated by means of a geared hoist. The door is interlocked and weathersealed to minimize dust infiltration. This door is large enough to pass the SNAP Unit nose cone in a vertical position on ground transport equipment. In addition, two personnel hollow metal doors at the east and west ends of the high bay permit emergency exit from the high bay to the outside. Emergency showers and eye wash basins are located at these exits. There are no windows in the high bay area.

The concrete slab floor is designed to support 16,000-lb wheel loads. The surface of the floor is sealed for protection and cleanliness. Removable stanchions in the floor protect the SNAP Unit work area from inadvertent collision with mobile equipment.

Covered floor trenches in the receiving and checkout area of the high bay carry power and test wiring. The 1-ft by 1-ft trenches are covered by removable checkered plates capable of supporting the 16,000-lb wheel loads. Ends of the cover plates are designed to prevent objects from falling into the trench. The trenches are provided with a drain. The ceiling of the high bay is exposed metal roof decking. Normally only two SNAP Units will be in the

building at any given time. The movement and control of these units within the area is discussed under Receiving in Section IV-E.

3. Low Bay

The low bay is a 46-ft by 60-ft partitioned area which provides space for the facility support functions. These consist of the instrumentation calibration and maintenance laboratory, machine shop, office space, locker room and rest rooms, boiler equipment room, and fan equipment room.

- a) The instrumentation calibration and maintenance laboratory is 15 ft wide and 20 ft long in which spare instrumentation and calibration equipment will be stored and maintained. Electronic work benches are conveniently placed for routine maintenance and repair of instrumentation components. This room is equipped with an independent air conditioning and heating system complete with intake dust filters and controls for automatic operation.
- b) The machine shop is 21 ft by 22 ft, equipped to maintain the facility and to perform minor repairs on the SNAP Units. A cleaning basin with a fume hood is also located in this room.
- c) The office area consists of three 8-ft by 10-ft offices. One is 9 ft by 19 ft and another is 12 ft by 22 ft (reception and clerical area). These areas will be supplied with desks and cabinets for supervisory, engineering, technical and clerical personnel. In addition, a 15-ft by 22-ft partitioned room is provided for conferences or additional office space as required.
- d) A men's locker room and a women's rest room are provided adjacent to the high bay area.
- e) The boiler equipment room is 12 ft by 15 ft, located on the northwest end of the low bay and furnished with forced hot water gas burning heating equipment.
- f) The fan and equipment room is 9 ft by 14 ft, adjacent to the high bay area, and houses the forced ventilation fan equipment for the high bay area.

In the low bay area there are four exterior doors. As shown in Figure 4, two are double hollow metal doors and two are single metal doors. Travel from the low bay area to the high bay area is through either of two interior double fire-rated doors, one from the machine shop and the other from the main corridor.

C. SERVICE SYSTEMS

A number of service systems are installed in the SNAP Prelaunch Test Facility to provide proper working conditions, fire protection, radiation warning, electrical supply, and material handling equipment for operations.

1. Heating, Ventilating, and Air Conditioning

The building is supplied with three separate heating and ventilating systems to serve the office, high bay, and machine shop areas. The Instrumentation Calibration and Maintenance Room is served independently by a mechanical heat pump air conditioning unit mounted on the roof. Heating requirements for the high and low bay are supplied by a single gas burning forced hot water boiler. The boiler has three hot water circulating pumps; one for the high bay area, one for the office area, and one for the machine shop.

Filtered air is circulated throughout the building by three ventilating fans with a capacity of $1900 \text{ ft}^3/\text{min}$ in the office area, $1900 \text{ ft}^3/\text{min}$ in the machine shop, and $6100 \text{ ft}^3/\text{min}$ in the high bay area. The air is heated as required by heating coils at the fan inlet and moves through a system of ductwork to the area supply registers. The offices and shop areas are provided with 15 air changes/hr and the high bay with 10 air changes/hr based on a 15-ft height. Air pressure in the low bay is maintained at a higher pressure than the high bay. The high bay is maintained at a slightly positive pressure, with respect to the outside atmosphere, to assure clean filtered air into the area, thus, minimizing the infiltration of dust.

All ventilation ducts which pass through partition walls contain fire dampers equipped with fusible link-type controls and access doors. In the event of an accident involving toxic material release, the entire high bay ventilation system can be shut off manually by the Supervisor, (by the use of a master control switch located near the front entrance of the low bay area), thus assisting in the containment of toxic materials in the high bay. To isolate the high bay, a spring loaded back-pressure relief damper is provided in the ceiling and a back-pressure damper is installed in the return duct.

2. Fire Protection Systems

The Prelaunch Test Facility fire detection and control systems consist of heat actuated detectors, signal sounding appliances (alarms and warning horns),

manual fire alarm boxes, control unit and portable MET-L-X and CO₂ extinguishers. Because of the presence of NaK, water sprinkler systems are not used for fire protection in the SPTF. Available volume of liquids for other uses will be limited to 5 gal. There will be three types of fire extinguishing equipment used in the facility:

- a) Portable water pump cans (low bay only).
- b) Portable high pressure CO₂ (for fires other than NaK fires).
- c) Portable dry calcium carbonate and MET-L-X (for NaK fires only).

The low bay area is supplied with heat-actuated detectors to operate the alarm bells. Portable CO₂ and portable water pump cans are provided to control the fire. The combination rate-of-rise and fixed temperature heat sensing fire detectors will activate the fire warning alarms and horns in the facility as well as transmit alarm signals to the VAFB fire department control center. The warning alarms and horns will be audible from any point within the building. A warning horn is also located on the outside east wall of the high bay. Manual fire-alarm boxes are located near the exits of the high bay and sound the fire warning alarms when activated. The location of the various fire protection systems are shown in Figure 6. In addition, the following equipment will be provided in the facility:

- a) Self-contained breathing apparatus units complete with demand air mask, air cylinder, and container.
- b) Bags of commercial calcium carbonate powder to be stored in the storage room for NaK spills.
- c) Two 150-lb MET-L-X wheel unit extinguishers.

At times when the SNAP power system units are in the facility, an experienced VAFB fireman will patrol the building during non-working hours. The VAFB fire department will have the capability for fighting fires involving pyrophoric materials. The special fire fighting problems associated with the operation of the facility will be made known to the VAFB Fire Department. Signs will be posted "Use No Water For Fire." Actuation of the fire alarm system requires immediate notification of the Fire Department, as operating personnel are not allowed to turn off any fire protection system. All fire control equipment is maintained and inspected by the VAFB Fire Department.

Figure 6. SPTF Protection Systems

3. Radiation Alarm

A radiation alarm system will be in operation at all times when a SNAP Unit is present in the SPTF. The alarm system will consist of a radiation detector probe located in the high bay and a station readout located in the instrumentation room. In the event radiation levels in the high bay exceed the preset limits, the system will activate a siren and a rotating red beacon on the roof of the building. In addition, an alarm signal will be transmitted to the crash-control center of the VAFB fire department.

4. Electrical

Commercial electrical power service is installed in the building. Local substations transform the power to the following services: 480-volt, 208-volt, and 120-volt, 3-phase supply for general service and lighting requirements. A 120 vac regulated voltage supply is provided for the instrumentation laboratory. A 28 volts supply is provided in the high bay and instrumentation laboratory. A separate power supply connection before the 480-volt station circuit breaker is provided to power the fire alarm system, and the facility exit lights. Standby batteries for the fire alarm system and emergency lights are provided in case of power failure.

5. Equipment Handling

The material handling equipment provided with the facility consists of a 3-motor, 5-ton, traveling, overhead crane in the high bay (described in Section II-B); small hoists for the machine shop and miscellaneous service; and general purpose hydraulic jacks. The special aerospace ground equipment to be used in the facility for handling the SNAP Unit components is described in Section IV. Equipment pads are provided adjacent to the building to accommodate miscellaneous equipment and to facilitate equipment handling of parts and components in and out of the building.

D. SECURITY

The entire area surrounding the SPTF is fenced off by a chain link fence. Two personnel gates and one vehicle gate are provided for access. Guard service will be provided by VAFB and will be in compliance with base operations and AEC security regulations. At such times as when SNAP Units are in the SPTF, 24-hr guard service will be provided at the facility.

III. DESCRIPTION OF SNAP 10A UNIT

A. GENERAL DESCRIPTION

The SNAP 10A Unit is designed to provide 500 watts of continuous electrical power to the payload of a space vehicle for a period of one year (Figure 7). The SNAP 10A Unit consists of a compact nuclear reactor as a heat source, cooled with liquid metal coolant (NaK alloy) and coupled to a thermoelectric power conversion unit. A thermoelectric dc conduction pump is used to circulate the coolant from the reactor to the thermoelectric converter-radiator unit which converts part of the reactor heat to electrical power and rejects the excess heat to space by radiator fins. Electrical energy is produced in the thermoelectric conversion process by maintaining a temperature difference between opposite faces of thermoelectric materials. The temperature differences are maintained by the liquid metal coolant in tubes on the hot side and aluminum radiator fins dissipating heat to space on the cold side. Other major components in the system include the radiation shield, the coolant expansion compensator, and the reflector control assembly.

B. REACTOR

1. General

The reactor uses a fully enriched uranium-zirconium hydride material as the combined fuel-moderator and beryllium as the reflector (Figure 8). The reactor core vessel is 9 in. in diameter and approximately 16 in. high, exclusive of control reflector assembly. The reflector control assembly is a separate unit which is adjusted and tested completely prior to installation on the reactor. This design also allows the control assembly to be removed from the reactor for maintenance or modification without disrupting the reactor or coolant piping.

2. Reactor Core

The reactor core is comprised of 37 cylindrical fuel-moderator elements 12-1/4 in. long. The elements are composed of a homogeneous mixture of zirconium hydride and uranium (U^{235}), and are canned in a 1.25 in. -OD Hastelloy-N tube (Figure 9). The inside surfaces of the core element tubing and end cups are coated with a 3- to 4-mil layer of boron-free ceramic.

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Figure 7. SNAP 10A Unit

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Figure 8. SNAP 10A Reactor

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Figure 9. SNAP 10A/2 Fuel Element

The 37 elements are arranged on 1.26-in. centers in a triangular array to form a hexagonal right cylinder core, 8 in. across the flats, 9 in. across corners, and 12 in. long. The fuel moderator elements are supported and held laterally by grid plates.

3. Reactor Vessel

The reactor tank is a cylindrical vessel constructed of 0.032-in. -thick, Type 316 or 321 stainless steel with welded top and bottom heads. The core vessel extends beyond the fuel elements to form upper and lower plenum chambers. The plenums, together with coolant flow holes in the grid plates, provide the proper NaK flow distribution through the core.

C. SHIELDING

A shield assembly (Figures 10 and 11) is provided to protect the AGENA instrumentation from radiation damage. The shield acts as a shadow shield and is mounted below the reactor as shown in Figure 10. A stainless steel casing provides support for the shielding material.

D. REFLECTOR ASSEMBLY

In the flight system, reactor reactivity is controlled by the reflector assembly. It consists mainly of the reflector main block, control drums, reflector shims, ejection mechanisms, drum locking devices, and support bracketry as shown in Figure 12.

1. Fixed Reflector

The main reflector block is a beryllium cylinder approximately 2 in. thick with the same height as the fuel elements. The cylinder is split longitudinally to form two separate halves which are independently mounted. Each section contains two control drums. Provisions are made for mounting beryllium shims on the flat surface between the control drums on the reflector halves.

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Figure 10. SNAP 10A Shield Reactor Vessel Assembly

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Figure 11. SNAP 10A Shield Assembly

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Figure 12. SNAP 10A Control and Reflector Assembly

2. Control Drums

The four control drums are spaced at 90-degree intervals about the main block. The drums are solid segments of a beryllium with the same thickness as the main block. The drums rotate on bracketry and fit into a pocket machined in the main block. Beryllium shims are mounted on the flat surfaces of the drums to adjust drum worth. Drums are always in the full OUT position except during startup and operation. The two coarse control drums located 180° apart are moved inward by a snap-in spring device. The two fine control drums, also located 180° apart, are moved inward by the individual actuator motors which impart a controlled stepped movement to the drums.

3. Flight Control System

The reactor core is reflected by the beryllium with startup control accomplished by the angular rotation of the four semicylindrical beryllium drums. In the flight system configuration, the four control drum elements are held in the OUT position by squib-released detent locking pins. The squibs are fired by command when the system achieves a satisfactory orbit, thereby releasing the detent pins. Two of the control drums snap in to the full IN position under the spring action. The other two control drums begin simultaneously stepping in at the rate of $0.5^\circ/150 \text{ sec}$ by the two stepping actuator motors. When the reactor reaches the operating temperature, insertion of the drums is stopped as the startup temperature controller assumes control. This device moves the two control drums to maintain a constant temperature level during the startup xenon transient period (approximately 3 days at full power). Subsequent long-term control of the reactor will be supplied by the inherent temperature coefficients of reactivity and the burnable poison.

4. Mechanical Protective Devices

During handling operations in the SPTF and prior to SNAP Unit launch, mechanical protective devices are incorporated in the SNAP Unit design to provide the necessary safeguards during shipment to the SPTF. These include the shipping sleeve, void filler blocks, keyed drum locking arms, and the squib-operated locking pins. Installation of either the shipping sleeve or void filler blocks is accomplished during the prelaunch assembly and test program to ensure maximum safe condition of the reactor system at all times. These devices are described below:

a. Shipping Sleeve

The shipping sleeve consists of a two-piece sleeve installed around the core vessel during shipment of the SNAP Unit bare core assembly, as shown in Figure 13. It minimizes neutron reflection from any outside reflecting media and provides mechanical protection to the core vessel. It is a stainless steel structure with a number of cells containing boron poisoning. The sleeve is designed to be installed or removed mechanically with the reflector installation fixture. Each half is always installed or removed in conjunction with the corresponding reflector half as described in Section IV.

b. Void Filler Blocks

Two attachments called void filler blocks, as shown in Figure 12, are bolted to the reflector main block at all times when the reflector is installed on the reactor. (The void filler blocks are removed prior to launch.) The void filler blocks fill the voids when the control drums are rotated to the OUT position and prevent the drums from rotating inward. The blocks also provide a mechanical link that prevents the installation of the reflector assembly with the control drum in a reactive position. This feature is accomplished by having the reflector handling fixture attached to the void filler blocks and not to the reflector assembly, thereby making it impossible to handle the reflector without the void filler blocks in place.

c. Keyed Drum Locking Arms

Each control drum is locked in the OUT position by key operated locking arms which attach to the reflector main block. The locking action is achieved by insertion of a stop (arm) in a slot in the control drum which prevents drum rotation. A spring latch prevents the removal of the drum locking arms from the snap-in drums unless the locking pins (d.) are in place. Four different keys, one for each lock, will be used for the drum locking arms. Keys will be under control of the Launch Operations Supervisor.

d. Squib Operated Locking Pins

Drum locking pins are also provided for each control drum. The pins also hold the drums in the OUT position and can only be withdrawn by actuating one of the two firing squibs for each drum. Squib pyrotechnics are not installed at any time during SNAP Unit handling at the SPTF.

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Figure 13. SNAP 10A Shipping Sleeve

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E. NaK HEAT TRANSFER SYSTEM

The SNAP Unit heat transfer coolant medium is NaK-78, a liquid metal (eutectic sodium-potassium alloy) which removes heat from the reactor and transfers it to thermoelectric converter radiator units. The coolant is pumped through the reactor where it is heated. During the thermal acceptance tests of the SNAP Unit prior to delivery at the SPTF, the coolant will be heated to a temperature of 990°F for complete system checkout. Coolant flow distribution and instrumentation sensors are shown in Figure 14.

The coolant leaving the reactor vessel passes through the integral power source pump and then into a tee section where the flow divides into two tubes. The tubes cross over the top of the core vessel and extend down along by the core and shield top into the converter upper manifold. From the upper manifold, the coolant flows down to the lower manifold through 40 converter tubes. From the lower manifold, the NaK coolant flows upward into the reactor vessel lower plenum chamber through two return tubes to complete the cycle. The NaK coolant is pumped by means of a dc Faraday conduction pump. The pump consists of a thermoelectric element, space radiator, magnet, fluid channel, and busses for an external power supply. The pumping power is derived from the Seebeck voltage developed in the thermoelectric converter which is mounted as an integral part of the pump (Figure 8). Attached to the coolant system are two volume expansion compensators. These compensators are bellows devices which maintain a void-free coolant system and regulate the system pressure under all expected temperature conditions. All portions of the heat transfer system contacting the coolant are fabricated from stainless steel materials except for the fuel elements and grid plates which are Hastelloy.

F. POWER CONVERTER-RADIATOR

The converter-radiator converts the reactor heat energy into useful electrical power (Figure 15). The converter-radiator is a conical shaped frustum approximately 7 ft high with end diameters of 2 and 5 ft. The converter-radiator is composed of an array of 40 D-shaped fluid tube assemblies connected to the inlet and outlet manifolds. The tubes are held in the conical shape by the supporting structure. A total of 72 thermoelectric converter elements are mounted on the tubes of each leg assembly. The thermoelectric material is a silicon germanium alloy. The element attaches to the tube through a copper hot strap,

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Figure 14. Coolant Flow and Instrumentation Location Schematic

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Figure 15. Thermoelectric Converter - Radiator

insulating and compensating materials. Aluminum radiator fins are attached to the thermoelectric elements. The liquid metal flowing in the tubes maintains the hot junction temperature while the radiators radiating excess heat to space provide the cold junction. The temperature difference across the thermoelectric elements results in the electrical power output. The aluminum radiator is fabricated in trapezoidal segments so that each thermoelectric element has an individual radiator. Alternate radiators are connected by a copper bar which provides an electrical connection between thermoelectric elements.

G. STRUCTURAL SHELL

The shell consists of a structural right circular cone frustum with 40 convolutions positioned radially on the perimeter and extending the full slant height. Support rings are riveted to the cone at various locations for support. The structure collects the loads imposed by the main components and transmits them to the lower support base ring. These loads are in turn transmitted to the AGENA vehicle through 8 support legs (Figure 7).

H. EJECTABLE HEAT SHIELD

A heat shield is used to prevent the NaK from freezing when the SNAP Unit is in orbit prior to system startup. The shield, as shown in Figure 16, consists of a sandwich aluminum honeycomb structure, concentrically mounted around the converter-radiator and extending from the reactor base to the lower support ring. The shield is made in two halves, split lengthwise, to allow for its ejection during the startup sequence. Special emissivity and absorptivity materials are used to cover the shield.

I. THERMAL BARRIER

The thermal barrier is a blanket of heat resistant material located across the bottom of the support structure. The heat barrier limits the heat flow to the AGENA vehicle and provides a low-temperature environment for the instrument compartment. The center section of the heat barrier is removable to allow installation and removal of the nuclear radiation shield.

J. INSTRUMENT COMPARTMENT

The instrument compartment is located below the thermal barrier between the SNAP Unit and AGENA vehicle. Most of the instrumentation associated with

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Figure 16. SNAP 10A Ejectable Heat Shield

the SNAP Unit is located in this compartment. The heat conducted to the instrument compartment is radiated to space.

K. STARTUP AND CONTROL SYSTEM

The startup and control system is used to control reactor outlet temperature during startup and for about three days in orbit until equilibrium conditions are reached. Subsequent long-term control of the reactor will be supplied by the inherent temperature coefficients of reactivity and burnable poisons. The system consists of a controller, control drum actuators, temperature sensors, and miscellaneous relays and other circuitry.

L. DIAGNOSTIC INSTRUMENTATION

The diagnostic instrumentation is used to monitor the performance, degradation and malfunction of the SNAP Unit. It consists of transducers and signal conditioning equipment which provide signals to the LMSC failure, status, and ascent telemetry equipment. Most of this equipment is located in the instrument compartment.

M. NUCLEAR CHARACTERISTICS

1. General

Nuclear and kinetic parameters are presented in detail in Reference 2.

2. Reactivity During Reflector Assembly

The detailed changes in reactivities associated with the removal of the shipping sleeve and the installation of the reflector have been calculated to determine the safety margins during this operation. These values are shown in Table I.

N. SYSTEM PERFORMANCE SUMMARY

A few of the SNAP 10A system operating characteristics and parameters are presented in Table II.

TABLE I
REACTIVITY VALUES

Condition of Reactor		Reactivity	
On Right Side	On Left Side	With No Other Reflection In Air	With Single Human Body Standing Adjacent
Sleeve	Sleeve	-18.00	-17.70
Bare	Sleeve	-19.10	-18.80 -18.00*
Reflector with void filler blocks	Sleeve	-11.30	-11.00
Reflector with void filler blocks	Bare	-12.40	-12.10 -11.30*
Reflector with void filler blocks	Reflector with void filler blocks	-4.60	-4.30
Bare	Bare	-20.30	-19.20

*Body on bare side

TABLE II
SYSTEM REQUIREMENTS

Electrical Output	
Initial (w)	585
Year end (w)	525
Minimum voltage (v)	28.5
Number of Control Drums	4
System Weight Objectives (lb)	975
Converter Radiator	
Area (ft ²)	62.5
No. of radiators	2880
Avg. thickness (in.)	0.032
Fin effectiveness	0.91
Emissivity	0.89
Absorptivity	0.30
System Overall Dimensions	
Length (in.)	128.5
Diameter at large end of converter (in.)	49.5
Diameter at small end of converter (in.)	23.2

IV. REASSEMBLY AND TEST PROGRAM

A. GENERAL

This section is presented for information only. An operations manual (Bldg. 060) with detailed assembly and test procedures will be issued prior to operation of the facility. A separate hazards report will be prepared covering transportation of the SNAP Unit from Atomics International to VAFB.

Shipment of the SNAP 10A Unit will be made to the SNAP prelaunch test facility at VAFB after satisfactory completion of acceptance tests at the Atomics International Santa Susana Facility (Bldg. 019). The SNAP 10A systems are received in the SPTF as a group of subassemblies which are packaged separately in specially designed shipping containers. The operations to be performed in the SPTF will prepare and establish the SNAP Unit for flight readiness. Figure 17 shows a flow sequence of the final assembly operations and tests to be performed. The facility in conjunction with the support equipment has the capability for system checkout, test, repair, reassembly, and final flight readiness tests. No final assembly operations or tests will be performed on the SNAP Unit unless all parts are certified to be in the proper condition for these tests by the supervisor or his designee. The SNAP Unit subassemblies will be retained in the containers in the storage area until required for checkout and system assembly. Only nonnuclear checkout and functional tests will be accomplished in the SPTF (Sec. IV.F.2 & 3). After separate testing, the reflector-control assembly will be installed on the reactor using a formal integration procedure in conjunction with the key-controlled drum locking system and special reflector installation fixture. Satisfactory checkout of the unit and final circuit continuity tests will be followed by the mating of the SNAP Unit to the AGENA mating ring in the SPTF building. Following these tests, the assembled SNAP Unit will be placed in its shipping container and located in the storage area. At the proper time, the completely assembled SNAP Unit will be transported in the shipping container to the launch complex for further assembly checkouts atop of the AGENA vehicle.

B. FACILITY ACTIVATION

Before the SNAP 10A Unit assembly and test program is initiated in the SPTF, a facility activation program will be completed. The purpose of this program is to determine that all facility equipment is furnished in accordance with design

Figure 17. Prelaunch Test Facility Operations Flow Diagram

SNAP UNIT SHIPPING CONTAINER

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Figure 18. SNAP Unit Shipping Containers

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Figure 19. SNAP Unit Shipping Container Monitoring Equipment

specification. All facility equipment will be inspected, tested, and functionally checked out. Also during this period, all the SNAP Unit support, handling, check-out, and test equipment will be installed and made operational.

C. AEROSPACE GROUND SUPPORT EQUIPMENT

A complete set of handling equipment will be available at the SPTF to perform inspection, testing and reassembly operations and to provide such backup support as may be required for the launch pad operations. The main design features of this equipment together with a description of the shipping containers follows:

1. SNAP Unit Shipping Container

The SNAP Unit shipping container is composed of an inner and outer container as shown in Figure 18. The capability for purging and maintaining a low positive pressure of inert gas in the inner container is provided. Shock and vibration isolation between the inner and outer containers is also incorporated in the design. The container holds the SNAP 10A Unit in its handling fixture in a horizontal position. Approximate dimensions of the container are 8 ft in diameter, 18 ft in length.

a. Support Platform

Associated with the shipping container is a small platform that will fasten to the forward end of the shipping container and will support the monitoring equipment.

b. Flat Bed Trailer

The trailer is a standard commercial vehicle or the military equivalent. It is used to haul shipping containers from Santa Susana to VAFB or from VAFB to Pt. Arguello. Approximate dimensions and carrying capacity are 8 by 35 ft bed and a 5 ton or greater load capacity.

c. Shipping Monitoring Equipment

Monitoring equipment as shown in Figure 19 will accompany the SNAP Unit shipping container for recording and monitoring environmental variables. A remote display panel for monitoring equipment will be placed in the cab of the transport tractor. The equipment will sense and record: (1) an increased activity of gamma radiation, (2) a leak occurring in the NaK system, (3) excessive vibration and shock along all three axes during loading, unloading, or in transit,

(4) loss of argon pressure, and (5) decrease in ambient temperature. The monitoring equipment will be completely self-contained but will also be capable of being operated from any 115 vac, 60 cps power source. This equipment may also be used to monitor the reactor while the SNAP Unit is in the SPTF, either in the shipping container or out of the container.

The monitoring equipment will consist of the following items:

(1) Electric Power Plant

This power plant will be driven by a gasoline engine and will be capable of delivering 1000 w at 115 v, 60 cps for at least 10 hr. The power plant will contain a 12-volt starting battery which will also be used to supply the monitoring and alarm devices (less the recording equipment) through a dc-to ac-inverter in case of malfunction of the power plant.

(2) Instrumentation Cabinet

The instrument cabinet will be of weatherproof construction, and will contain the equipment described below:

(a) Oscillograph and Amplifiers

The oscillograph will be an electric writing, six-channel, militarized unit with two event markers.

(b) Power Supplies

The power supplies located within the control cabinet will supply the pen-drive amplifiers and the nuclear and nonnuclear instrumentation with the required power.

(c) Display Panel

The display panel will contain the instruments and indicating lights displaying the monitored data. It will also contain the push button and switches for controlling the instrumentation and for manual activation of the alarm devices.

(3) Remote Display Panel

The remote display panel will be functionally identical to the display panel located in the instrument cabinet, except that it will be used in the tractor cab. One or the other of the two display panels may be activated by means of a selector switch.

(4) Sensors

The required sensors will be mounted inside the inner shipping container, and will monitor the environmental condition of the SNAP Unit. The gamma radiation sensors will also be utilized outside the shipping container.

(5) Alarm Device

A horn will be mounted in the instrumentation cabinet. Horn operation will be initiated by a signal from the sensors. The horn will be capable of being silenced from either the instrument display panel or the remote display panel.

(6) Interconnecting Cables

The following interconnecting cables will be required:

- a) Instrument Cabinet to Power Plant Cable
- b) Instrument Cabinet to Shipping Container Cable
- c) Instrument Cabinet to Remote Display Unit Cable
- d) Instrument Cabinet to External Alarm System Cable

(7) External Alarm System Connector

The alarm triggering devices of the monitoring equipment will be grouped into a nuclear and a nonnuclear series circuit. These circuits will terminate at a connector for tying into the external alarm system.

2. Reflector and Radiation Shield Shipping Containers (Figure 18)

Separate shipping containers are provided for the reflector assembly and radiation shield. These containers have provisions for maintaining a controlled environment over the enclosed contents.

3. Heat Shield Shipping Container

This item is a conventional weathertight container used to enclose and protect the ejectable heat shield during handling and shipment.

4. SNAP Unit Handling Fixture

The SNAP Unit handling fixture provides the support, pickup points, and protection against damage of the SNAP Unit. Attachments to the SNAP Unit are

made at the upper and lower rings of the converter cone structure. Removable panels on the surface of the fixture provide protection for the radiators and also allow access to the cone. Trunnions are provided for mounting the fixture on the in-plant transporting dolly and the shipping container.

5. Tilt Sling

The tilt sling is used in conjunction with an overhead crane to hoist the SNAP Unit in its handling fixture from either a horizontal or vertical position. It can be used also to rotate the SNAP Unit from a vertical to a horizontal position or vice versa. (Figure 20)

6. Hydra-Set

This is a hydraulically actuated device that is inserted in the hoisting line to provide fine control of the lifting operations. The total travel is limited to 18 in. movement and is controlled to 1/64 in. Its use decreases the G forces to which the SNAP UNIT is subjected.

7. Vertical Handling Yoke

This yoke provides a method for handling the SNAP Unit vertically with an overhead hoist when the SNAP Unit is not in its handling fixture. The function of the yoke is to hoist the SNAP Unit from the vertical support fixture. The yoke consists of a ring configuration with four arms for attaching the yoke to the SNAP Unit upper torque ring.

8. SNAP Unit Work Platform

The variable height SNAP Unit work platform is used for a work area during inspection, testing and reassembly operations when the SNAP Unit is mounted on the vertical support stand. The design of this platform permits easy access to any portion of the vertically positioned SNAP Unit by raising or lowering the platform.

9. SNAP Unit Vertical Support Stand

The vertical support stand is a cylindrical work stand on which the SNAP Unit is mounted vertically. The vertical support stand for the SNAP 10A Power Unit is shown in Figure 21. The design permits both internal and external access to the converter. The stand consists of two flat rings separated by four vertical legs. The base of the SNAP Unit handling fixture is bolted to the upper ring of the support stand. The upper ring is large enough to

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Figure 20. Handling Fixture and Tilt Sling

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Figure 21. Vertical Support Stand for the
SNAP 10A Power Unit

permit personnel access to the interior of the converter cone and to allow installation of the shield assembly. The center of the stand provides the support for the hydraulically operated shield installation fixture. This fixture holds and positions the reactor shield during assembly.

10. Reflector Assembly Installation Fixture

A special fixture is used to install and/or remove the reflector assembly on the reactor vessel. This fixture provides safe and precise motion control of the actions during removal of the shipping sleeve and installation of the reflector assembly, assuring that the control drums are positively held in an OUT position by the void filler blocks during the assembling operation.

11. In-plant Dolly

The in-plant transporting dolly provides mobility to the assembled SNAP Unit and handling fixture. The four-rubber-wheeled dolly has an air bag suspension, shock absorbers, parking brakes, towbar and automotive knuckle type steering. The SNAP Unit can be supported in the vertical or in the horizontal position while on the dolly. The dolly is equipped with four adjustable leveling jacks enabling the dolly to be lowered, thus providing a work platform.

12. Electrical System Test Set (Type II)

The primary purpose of the test-set type II checkout equipment shown in Figure 22 is to aid in the performance of the prelaunch validation testing of the SNAP Unit system when the SNAP Unit is not mated to the launch vehicle. The test set will verify that the electrical circuits and subsystems are performing as designed and are functionally satisfactory for flight. The test set is designed for rapid evaluation of functional test results with a minimum of data reduction. Essential readouts are automatically displayed and recorded. This equipment will be connected to the SNAP 10A Power Unit through the test plugs provided during compatibility testing in the SPTF. The functions of the launch vehicle will be simulated and monitored by this test equipment.

D. PREPARATIONS FOR SNAP UNIT SHIPMENT TO SPTF

Although these operations are not performed at the SPTF, they are included here to provide a description of the SNAP Unit's condition upon arrival at VAFB.¹ Shipment from Santa Susana to the SPTF will begin after satisfactory completion of acceptance testing. A partial disassembly will be made in preparation for

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Figure 22. Electrical System Test Set (Type II) Functional Block Diagram

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shipment. (No pyrotechnics will be shipped with the SNAP Unit.) The beryllium reflector assembly, the radiation shield, and the ejectable heat shield are removed from the assembly and provided with separate shipping containers. Shipment may be made on the same vehicle with the SNAP Unit. A protective shipping sleeve is installed around the reactor core to prevent physical damage and to maintain the reactor subcritical in the event of accidental submersion in a hydrogenous fluid. The basic assembly is then mounted in the handling fixture. This fixture protects the converter surface and provides a means for supporting the structure in the shipping container (Figure 23).

After mounting the SNAP Unit in the handling fixture and placing it in the shipping container, the top half of the inner container will be fastened to the lower half. A special sling, an overhead crane and standard mechanic's tools are used in this operation. An inner container leak test will be performed by pressurizing to 3 psig with argon gas and noting that the leak rate is below 0.10 psig per 30 min. After passing the leak test, the container is bled to 2.5 psig. The outer container is then installed and bolted together. The complete container is placed on the flat bed trailer. Instrumentation connections to the monitoring equipment are made with readouts and alarms being located in the cab of the tractor. A supply of argon gas is carried aboard to service the SNAP Unit or reflector container as required to keep the minimum pressure above 2.4 psig.

E. RECEIVING

When the shipment arrives at VAFB, it is delivered to the high bay area of the SPTF. The SNAP Unit subsystems will remain in the shipping containers until required for reassembly and testing with the SNAP unit. The SNAP Unit will be monitored while in storage. If one SNAP unit is undergoing testing and reassembly at the time another unit is received, the second unit will preferably be left in its shipping container until the first unit has been processed. (If it becomes necessary to work on more than one SNAP Unit at one time in the SPTF, it will be necessary to guarantee a minimum safe separation between units of 12 ft. Ref. Appendix B.) The receiving and inspection of the SNAP 10A subassemblies is the initial step in the testing and reassembly program for each SNAP Unit. The items to be received are as follows:

- 1) The SNAP Unit stored in its double-walled, hermetically sealed shipping container.

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Figure 23. Shipping Sequence Breakout

- 2) The lithium hydride reactor shield in its specially designed shipping container.
- 3) The reflector assembly in its special shipping container.
- 4) The heat shield in a conventional shipping container packaged for protection against the weather.

Although the shield and reflector assembly are packaged under an inert gas pressure, the environment is not monitored on these subassemblies during storage and shipment. These units are shipped separately to provide additional safety measures and to minimize in-transit damage.

F. INSPECTION AND TEST OPERATIONS

After the various subassemblies are received and stored in their proper locations, the operations shown on Figure 17 follow. Inspections, tests, and final reassembly operations are regulated by detailed procedures which are a part of the operations manual. The following operations are performed:

1. Inspection

Detailed procedures are used to take inventory and to inspect all equipment received from Santa Susana. If there are signs of damage or the trip log indicates that the shipping environment limits have been exceeded, the receiving inspection procedures will prescribe the action that must be taken.

a. Evaluation of the Shipping Operation

The trip log is reviewed and events that could have caused damage are noted. Parameters that have been automatically or manually recorded are studied to determine if any abnormal condition has occurred during the trip. The shipping containers and mounting fixtures are examined for any evidence of physical damage; if none exist the containers are then placed on pallets preparatory to removing the equipment from the containers. If there are signs of damage, the appropriate safety measures will be taken during unpacking operations.

b. Removal from Shipping Containers

With the exception of the SNAP Unit, all items are first removed from the shipping containers, inventoried, inspected for damage, and then replaced in the containers. Any possible damage is noted in the SNAP Unit System Log Book. If container cover gas has been used, the container will be vented before opening.

The SNAP Unit is removed from the shipping container (Figure 23) and placed on the vertical support stand using the appropriate handling equipment as described in Section IV-C. The subassembly is physically inspected to determine that the geometry and appearance is in accordance with the design drawings, thus assuring that no apparent physical damage has occurred during shipment. If obvious damage has occurred and it is not repairable at SPTF, the item will be repacked and returned to Santa Susana for repair.

The reflector assembly is then removed from the shipping container and mounted on a dummy reactor vessel. Physical inspection is made for damage and it is examined electrically for continuity and circuit resistance. Next, the reactor shield assembly is removed and inspected.

The ejectable shield will be inspected for damage. The pyrotechnics (which have been shipped separately) are examined in an area designated safe for such procedures. The pyrotechnics are stored in magazines provided by VAFB.

c. SNAP Unit Assembly Inspection

After removal of the unit from the shipping container, a thorough check-out is required.

(1) Structural Integrity

The thermoelectric converter is inspected closely for indications of separation of the elements from either the NaK tubes or heat radiators. Cracks, chips, dents, and other indications of rough handling will require further inspection.

(2) Electrical Check

The thermoelectric converter is checked for continuity and resistance. Modules are checked at this time. If there are any indications of possible damage, the individual elements will be tested.

d. NaK System

The NaK system is checked for leaks or any signs of other damage. The possibility of such damage is unlikely, because the SNAP Unit is shrouded and protected by the handling fixture during shipment and storage.

e. Electronic Components

The electronic components are checked for continuity and proper circuit resistance. The mounts and electrical connections are inspected for tightness.

2. SNAP Unit Testing and Checkout

After the physical inspection is completed, the electrical system test set is used to check continuity and measure converter loop impedances. These measurements will be compared with values obtained during the acceptance tests at Santa Susana.

3. Startup Sequence Tests

The following startup sequence tests are executed to check the startup and control circuitry, operation of the actuating mechanisms, and control drum movement of the reflector assembly. During testing, the reflector assembly is mounted on a simulated core which is remotely located from the SNAP Unit. At this time the SNAP Unit is on the vertical support stand with the shipping sleeve in place around the reactor.

The electrical system test set Type II (Figure 22) is connected to all test and interface plugs. Jumper cables are connected between the SNAP Unit control and sensing circuits and the reflector devices and sensing devices. Under the above conditions, the SNAP Unit undergoes simulated orbital startup operation including all of its failure modes. All circuits are activated by actual signals or simulated signals expected during reactor and converter operation and the response of all instrumentation is checked. Squib circuits are continuously analyzed to assure that squibs cannot be energized by induced spurious signals in the control circuitry. Simulated firing of squib release mechanisms is accomplished by means of high pressure gas in order to check operation of eventmarker switches, control drum limit switches, and control drum movement. Upon completion of the tests, the reflector assembly is returned to the shipping container.

G. REASSEMBLY OPERATION

After testing is completed, the radiation shield, reflector assembly, and temperature-actuated release devices are installed. The center of gravity of the complete assembly is determined. The AGENA/SNAP Unit mating ring is installed. The ejectable heat shield and AGENA/SNAP Unit nose fairing are next fitted in place and then removed for shipment to the launch complex.

1. Radiation Shield Installation

The SNAP Unit in its handling fixture is removed from the vertical support stand and placed on the floor. The shield installation fixture and hydraulic

jack are attached to the center of the vertical support fixture. The reactor shield is placed on the support cup of the shield installation fixture (Figure 24). The SNAP Unit is then repositioned on the vertical support stand over the shield. The reactor shield is raised into position using the hydraulic jack and the shield is then attached to the SNAP Unit structure. The design allows personnel access inside the SNAP Unit to finally fasten the shield to the structure. During this operation, the installation of the reactor shield does not change the reactivity of the reactor any significant amount.

2. Reflector Assembly Installation

After completing the shield installation on the SNAP Unit subassembly, the reflector assembly is installed. During this operation, the SNAP Unit is located on the vertical support stand in the handling fixture. The reflector assembly installation fixture is attached to the SNAP Unit handling fixture. This is the only operation that is performed in SPTF in which there are significant reactivity changes. To assure maximum safeguards in this operation, a set of mechanical keyed interlocks and controlled procedural sequences are employed. The interlocks and procedures prevent the following:

- a) The existence of a bare reactor core during any part of the operations in the facility.
- b) An uncontrolled rate of reactivity insertion when installing the reflector assembly.
- c) Installation of the reflector assembly without the void filler blocks in position on the reflector assembly.

Before the reflector assembly can be installed, the drum locking arms and the restraining void-filler blocks must be in place on each half of the reflector assembly. The lockout devices are shown in Figure 12. The sequential steps used to install the reflector assembly are given in Figure 25. During all of these steps, the four control drum keyed locking arms prevent drum rotation. Also, the void filler blocks restrain the drum motion by occupying the drum operating space, thus preventing any other material from entering the space and causing changes in reactivity. The drum locking arms are locked by keys. Under no condition, after reflector assembly, will the arms be removed except just prior to launch. In conjunction with the installation of the reflector assembly, the

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Figure 24. Installation of Radiation Shield Assembly

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1. SNAP UNIT IN HANDLING FIXTURE (VERTICAL), HANDLING FIXTURE CAP REMOVED.
2. SHIPPING SLEEVE (CORE VESSEL PROTECTION SHIELD) IN PLACE.
3. FOUR REACTOR VESSEL LOWER HINGE PINS REMOVED.
4. REFLECTOR INSTALLATION FIXTURE (TRACKS & CARRIAGES) ATTACHED TO UPPER SURFACE OF HANDLING FIXTURE.
5. REFLECTOR ASSEMBLIES INSTALLED ON CARRIAGES. (TURRETS ROTATED SO THAT REFLECTOR ASSEMBLIES FACE AWAY FROM REACTOR. A TRANSFER LOCK SYSTEM WILL BE USED TO LOCK CARRIAGE A AND CARRIAGE B SO THAT ONLY ONE CARRIAGE CAN BE UNLOCKED AND MOVED AT A TIME.)
6. ROTATE CRANK TO DRIVE CARRIAGE (A) INTO POSITION TO ATTACH CARRIAGE TO SHIPPING SLEEVE BY MEANS OF ATTACH POINTS. REPEAT FOR CARRIAGE (B).
7. REMOVE SHIPPING SLEEVE RETAINERS. (SLEEVE HALVES NOW HELD IN POSITION BY CARRIAGES (A) & (B)).
8. ROTATE CRANK DRIVING CARRIAGE (A) AWAY FROM THE REACTOR TO THE END OF TRAVEL.
9. ROTATE TURRET (A) 180° INTO POSITION SO THAT REFLECTOR ASSEMBLY NOW FACES THE REACTOR. (SHIPPING SLEEVE HALF MAY NOW BE REMOVED FROM CARRIAGE, IF DESIRED)
10. INSTALL TWO REFLECTOR EJECTION SPRINGS ON "A" SIDE OF REACTOR AND COMPRESS WITH SPRING COMPRESSING TOOLS.
11. ROTATE CRANK TO DRIVE CARRIAGE (A) TOWARDS REACTOR ASSEMBLY TO A POSITION CLOSE TO THE REACTOR. ADJUST POSITION OF REFLECTOR BY MEANS OF ADJUSTMENTS ON CARRIAGE SO THAT THE REFLECTOR HINGE HALVES ALIGN WITH THE REACTOR VESSEL SUPPORT HINGE HALVES.
12. ROTATE CRANK TO DRIVE CARRIAGE (A) TOWARDS THE REACTOR UNTIL THE LOWER HINGE PIN HOLES ARE IN LINE. INSTALL THE LOWER HINGE PINS & SAFETY.
13. REPEAT STEPS 8 THROUGH 12 USING CARRIAGE (B) TO REMOVE THE OTHER HALF OF THE SHIPPING SLEEVE & INSTALL THE OTHER REFLECTOR ASSEMBLY HALF.
14. INSTALL THE REFLECTOR ASSEMBLY RETAINER BAND.
15. REMOVE THE FOUR REFLECTOR EJECTION SPRING COMPRESSING TOOLS.
16. DETACH CARRIAGE ATTACHING SCREWS FROM VOID FILLER ASSEMBLIES ON THE REFLECTOR ASSEMBLIES. ROTATE CRANKS TO MOVE CARRIAGES (A) & (B) AWAY FROM THE REFLECTOR ASSEMBLIES.
17. REFLECTOR ASSEMBLIES ARE REMOVED & SHIPPING SLEEVES INSTALLED USING THE REFLECTOR INSTALLATION FIXTURE AND SIMILAR PROCEDURES.

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Figure 25. Reflector Installation

temperature-actuated release devices are also installed. Detailed reactivity changes for this operation are given in Appendix C.

3. Final Assembly

After the completely assembled SNAP Unit has demonstrated that it meets all design requirements, including determination of the center of gravity, the SNAP Unit will be mechanically checked for AGENA mating ring and nose fairing compatibility with the ejectable heat shield in place. These checks will give assurance that the SNAP Unit will mate properly with the AGENA mating ring and that the SNAP Unit can be prepared for launch with the nose fairing in place. None of the pyrotechnics, such as the drum locking pin squibs, ejectable heat shield squibs, compensator squibs, or the destruct charge, are installed in the facility. Consequently, there will be no handling of pyrotechnics in the SPTF.

The SNAP Unit is lifted vertically and the AGENA/SNAP Unit mating ring is inserted between the SNAP Unit and the vertical support fixture. The SNAP Unit is then lowered onto the ring and the proper connections made.

Next, the SNAP Unit handling fixture is removed and the ejectable heat shield is fitted around the thermoelectric unit of the SNAP Unit and checked for clearance. The ejection mechanism is partially tested using simulation of the squib release device.

The SNAP Unit/AGENA aerodynamic nose fairing and cap is placed over the SNAP Unit and checked for proper clearances using LMSC handling equipment. The access ports in the nose cap are checked for obstructions and clearances by an operator inserting his arm through the opening and feeling the drum locking arm key locks. Drum locking arms or void filler blocks are not removed or altered at this time. This operation is performed by one man as are all operations adjacent to the reactor. At this time the shutdown margin will change to a minimum (refer to Table I, page III-17. This minimum shutdown margin is based on the reflection of a single human standing adjacent.

4. Final Checkout and Preparation for Shipment

After removing the nose cone fairing and the ejectable heat shield from the SNAP Unit, the entire system is checked by visual inspection and electrical continuity tests. The SNAP Unit handling fixture is reinstalled to support the unit during further handling. The SNAP Unit is hoisted in a vertical position and

by use of the tilt sling is turned 90° to the horizontal position (Figure 20). The SNAP Unit is placed in the shipping container where it will be stored until required at the launch pad. While in storage the inside container compartment is pressurized with inert gas and the container monitoring instrumentation is in operation. The SNAP Unit, as stored in the shipping container, is a complete flight-ready system except for the installation of the ejectable heat shield and pyrotechnics. The ejectable heat shield is stored in the same shipping container used for transporting it from Santa Susana to SPTF. The squibs, destruct charge, and associated ignition mechanisms will also be transported to the launch complex as required from the VAFB storage area.

H. MINOR REPAIRS AVAILABLE AT SPTF FOR THE SNAP UNIT COMPONENTS

Repair capability will include the following:

- 1) In event of NaK leak in the heat transfer system — remove NaK from the system, purge system with argon or helium and maintain a slight positive pressure on the system. Return unit to AI for repair.
- 2) Correction of minor structural damage — reinforcement of structural parts by riveting or welding.
- 3) Replacement of electrical components — electronic components that fail to pass electrical tests will be repaired or replaced. Minor wiring changes also will be accomplished.

Equipment such as welding machines, leak detectors, portable hand tools, electronic test equipment, will be available at SPTF for repairs. Complete repairs to the electronic equipment will be made in the instrument room as necessary.

1. NaK Handling

Normally, NaK will not be handled at SPTF. However, under some circumstances it may be necessary to drain the systems in the event of a NaK leak. If such repairs become necessary, the NaK handling operations will be performed by personnel trained in the safe handling of this material. All personnel involved in this operation will wear the recommended protective clothing for handling NaK. Fire fighting equipment, emergency breathing apparatus, and other required supplies will be on hand during the operations.

After the drain and purge operation is complete, the fill lines will be sealed to assure a leak-tight system.

2. Leak Checkout

If a NaK leak is apparent from the shipping container monitoring system or should one occur during the operations at SPTF, the location and extent of the leak will be determined, if possible. First, visual inspection will be made to locate the leak. During this time the same safety precautions will be in effect as when handling NaK, as previously described. The NaK will be drained from the unit at the SPTF into an appropriate container, the NaK being kept underneath white mineral oil at all times. The system will be drained and purged with inert gas. The location of the leak will be identified using helium and mass spectrometer leak detection equipment. The leak will be sealed using proven techniques for liquid metal systems to prevent leakage of the inert gas. The system will be returned to Santa Susana for leak repair.

I. PROCEDURE REVIEW

The procedures for operating the facility and for testing and final reassembly will be kept up to date. When it becomes apparent that the approved procedure will have to be modified, a procedural change will be initiated. This entails the following operation:

- 1) Fill out Procedure Review Form making the necessary changes in the procedure.
- 2) Obtain the necessary approvals as specified in the form.
- 3) Reproduce copies of the procedure change and distribute to the operations personnel.
- 4) The operations personnel will then insert the changes in their manuals and log the changes in their Procedure Revision Log fly sheet.

The Procedure Review Form will be filled out by a member of the operations unit who is familiar with the operational problems and the procedure will be approved by the Health Physicist. In the first section, the present method shall be described. This description will not be a step by step account but the general method proposed to do a specific operation. The second section will present the proposed change in method. The third section will present the reasons for the

proposed change. Where applicable, the appropriate sections in the Safeguards Report will be referenced to indicate that the changes are within its limitations. The fourth section will present the new procedure. The section in which the procedure change appears shall be presented in its entirety. The fifth section will have the new check sheet for the revised section. The sixth section will provide space for the necessary reviews and approvals.

PROCEDURE REVIEW FORM

Procedure Title

1. Present Method
2. Proposed Change(s)
3. Reasons for Change(s)
4. New Procedure
5. New Check-Off Sheet
6. Approvals:
 - a) Supervisor or Designee
 - b) A.I. Base Manager
 - c) A.I. Health Physicist

J. TEST REQUEST

It is anticipated that during the final testing program, additional testing may be required. The operations to be performed during these tests will be controlled by standard procedures. All special tests will be initiated in the following manner:

- 1) The procedure will be written in the standard format previously described.
- 2) The Test Request Form is filled out and attached to the procedure.
- 3) The Test Request Form and procedure will then be submitted for the necessary reviews and approvals.

K. SNAP UNIT MODIFICATIONS

During final testing and reassembly operations, minor modifications may become necessary. All proposed modifications will be submitted to AI Project Management for approval and decision as to where the work will be performed. Administrative control over these operations will be effected by detailed procedures.

V. OPERATION

A. GENERAL

The following outlines the standards for controls, procedures, and approvals involving: (1) organizational responsibilities and authorities; (2) recording and approval of operating activities; (3) development, approval, and updating of hazards reports; (4) development, approval, and maintenance of facility and operations manuals; and (5) development and approval of special test procedures.

B. OPERATIONS RECORDS

The SPTF will require the following operations records:

1. Facility Check Sheet

A bihourly check will be made when test or reassembly operations are in progress in order to insure that the SPTF is in a safe operating condition. When reassembly operations are not in progress a check will be made once a day. The data will be kept in the Facility Check Sheet Book which will be located in the Supervisor's office.

2. Test or Final Reassembly Check Sheet

Each prelaunch test and final reassembly operation will be detailed in a step-by-step procedure. A Test or Final Assembly Check Sheet will be an integral part of these procedures. The check sheet is divided into four sections as follows: (1) test initiation, (2) completed step sign-off, (3) data recording, and (4) procedure completion sign-off.

The test initiation section of the sign-off sheet shall document that the operations personnel understand the procedure, and that all operation limits have been set and all pertinent initial system conditions are satisfied.

The completed step sign-off section insures that individual procedure steps are satisfactorily completed before new steps are initiated.

The data section will provide space for raw data and pertinent control curves for various tests.

The procedure completion section documents the primary fitness of the test or operation and verifies that the system is ready for the next test or final reassembly operation.

3. Instrumentation Maintenance Log

The facility instrumentation will be serviced on a routine basis and records will be kept in an Instrumentation Maintenance Log which shall be located in the Supervisor's office.

C. SPTF OPERATIONS PERSONNEL

- 1) The organizational structure will be typical of the Compact Systems Division for nonnuclear facilities.
- 2) Lead Engineer - The lead engineer is immediately responsible for the safe and efficient operation of the facility. He has full authority to stop any operation if, in his judgment, an unsafe condition exists. He is responsible for the complete recording of all pertinent data and information in the appropriate logs for the facility.
- 3) Supervisor or Designee - The supervisor has overall responsibility for the safe operation within the facility. He revises and approves test procedures, issues schedules, reviews all facility logs. He is responsible for the maintenance of operations manuals, the collection of supporting data, and the issuance of operations reports.
- 4) Group Leader or Base Manager - The group leader has overall responsibility for both facility operation and evaluation of the tests as they affect both program objective and safety. He is responsible for the development and issuance of overall program objectives and schedules. He reviews and approves all test procedures, safeguards reports and modifications to safeguard reports, operations manuals and modifications to operation manuals. He is responsible for initiating reviews by the Compact Reactor Committee of the Reactor Safeguards Review Panel of all activities under his jurisdiction which, in his judgment, warrant review or where review is required by procedure.

The operating staff of the SPTF will consist of several categories of personnel as outlined below:

- 1) During each SNAP Unit prelaunch test program, the facility will be operated on an 8-hr day shift basis but 24-hr coverage will be provided should schedules demand. The normal crew during operations will consist of the following personnel:

- 1 supervisor or designee
- 1 lead engineer
- 1 test engineer
- 3 mechanics
- 3 electrical technicians

Personnel will be responsible for final reassembly, all test-data reporting, and operation of auxiliary systems for the test program. In addition, other launch operations personnel will be available as needed according to the operation in progress, but in no case will the number be less than two.

- 2) Relief engineering personnel required for vacations, illness, etc., will be drawn from the analysis group listed in 4 below.
- 3) One instrument technician and one mechanic will be responsible for the preventive and emergency maintenance and will assist day-shift personnel as required.
- 4) Three engineers will be responsible for the day-to-day analysis and evaluation of the data obtained from SNAP Unit tests, maintaining close contact with SNAP 10A engineering groups to advise of any abnormal test results.
- 5) One health physicist will be responsible for all radiation measurement records of all personnel in the SPTF.
- 6) The supervisor will be responsible for engineering assignments, coordination, scheduling, and control of the testing program.

D. OPERATING PHILOSOPHY

1. General

The operating philosophy will be governed by the practices and standard operating policies of Atomics International Division of North American Aviation, Inc. Safety practices will be consistent with requirements of the Health and Safety Section. All of the operations to be performed will be consistent with the specific operating rules and procedures for the facility. The personnel performing various tasks shall have been trained and evaluated before being given the responsibility for these tasks.

2. Safety Standards

The safety standards for the facility shall be set in accordance with standard operating policies of the Health and Safety Section as they apply to standard operations covered in the manual. The facility rules and regulations shall be in effect at all times. Emergency and safe handling of hazardous materials procedures are covered in manuals published by the groups that are responsible for the use of these materials. The Atomics International departments responsible in these areas will be available to assist the VAFB personnel in an emergency.

E. OPERATING RULES

The following rules will apply to the operation of the SPTF:

1. High Bay

Entry into and the number of persons in the area shall be limited by the discretion of the supervisor or designee. During assembly operations of the SNAP Unit, only persons with specific work assignments, plus a limit of five nonduty personnel or visitors shall be in the area. Access to the high bay area is restricted at all times when the SNAP Unit is in the building. A facility guard is on duty at all times; however, operating personnel may leave the area at any time providing either the shipping sleeve or the reflector assembly and void filler blocks are properly installed.

2. Entry Adjacent to SNAP Unit

During the conductance of a test or assembly procedure, permission for entry into the roped-off work area adjacent to the SNAP Unit is required from the supervisor or designee.

3. Reflector Assembly Installation

The special tools required to remove the shipping sleeve, the keys for the control drum locking devices, and the reflector installation fixture shall be under the jurisdiction of the supervisor. These will be used only during the performance of an operation that is covered by an approved procedure and controlled by its check sheet.

4. Test Limits

The limits for the tests and assembly operations tests are specified in the individual procedures and are documented by the supervisor's or designee's signature in the Test Check Off Sheet.

5. Health Physics Criteria

The area immediately surrounding the Be reflector assembly, when the assembly is outside its container, will be designated as a Be area. No smoking, drinking, or eating will be allowed in this area. Gloves will be required for any operation involving actual handling of the reflectors. No additional protective clothing will be required unless smears of the area surrounding the reflector assembly indicate surface contamination levels in excess of $1 \mu\text{gm}/100\text{cm}^2$. No respiratory protection will be required unless air samples indicate airborne contamination levels in excess of $2 \mu\text{gm}/\text{m}^3$. When the Be reflector assembly is in place on the reactor, the area surrounding the reactor will be designated as a Be area as well as a radiation area. Radiologically controlled areas will be properly posted with signs indicating them as radiation areas. All persons working within these areas will wear film badges and pocket dosimeters, and will be radiation workers as defined by the AEC Manual.

F. EMERGENCY EVACUATION PROCEDURES

1. Notice to Evacuate

Notice to evacuate is given when necessary for personal safety, and will generally be ordered by one or more of the following:

- a) Verbal local or "in area" notice from responsible operating personnel or the health physicist at the scene,
- b) Public address announcement,
- c) Siren alarms.

2. Emergency Assembly Area

When notice to evacuate is received, all personnel not having emergency action responsibility will:

- a) Evacuate the facility promptly and carefully and proceed to the emergency assembly area (EAA) located approximately 400 ft down the access road, as illustrated by Figure 26.
- b) Remain there until the "all clear" is announced or until additional instructions are given.

A road block will be established on the access road, adjacent to the EAA to restrict entry into the facility.

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Figure 26. Evacuation Route and Emergency Assembly Area

An emergency kit, containing portable radiation survey instruments, personnel dosimetry devices, decontamination supplies, and first aid supplies, will be maintained in a readily accessible place in the guard station just inside the facility fence. This kit will be taken to the EAA during all evacuations of the facility.

Practice evacuations will be conducted at least two times a year. The launch operations supervisor will be responsible for personnel participation in practice evacuations to insure complete familiarity with procedures. This may require additional scheduling of evacuation practice other than that normally required by VAFB.

3. All Clear

The launch operations supervisor or his designee, acting with the necessary advice of the health physicist, will determine that the facility is safe for re-entry. No reoccupancy of the facility will be made until this determination has been communicated.

4. Fire

a. Building Occupied

In the event the fire alarm is activated, emergency evacuation procedures will be initiated. If a fire is discovered which has not activated the alarm system, the system will be activated manually by breaking the glass in the face of the alarm box prior to initiation of emergency procedures. The VAFB fire department will respond to all fire alarms from the SPTF.

The launch operations supervisor will designate members of the operational crew as auxiliary firemen who will be trained in fire fighting procedures. The auxiliary firemen shall take emergency action to minimize fire damage prior to the arrival of the VAFB fire department.

The launch operations supervisor or his designee shall be responsible for the following shutdown operations: test log evacuation; verification that all persons are present at the EAA or accounted for; obtaining of the emergency radiation kit; and if a high-bay area fire, shutdown of the ventilation system.

b. Building Unoccupied

In the event the fire alarm is activated during periods when the building is unoccupied, the facility guard, who will be trained in fire fighting procedures,

will assess the location and magnitude of the fire and take appropriate action based upon this assessment:

- 1) If the fire is located in the high bay area, the guard will call the responsible AI representative (supervisor or designee) and then retreat, with the emergency kit, to a point on the access road adjacent to the EAA where he will restrict entry into the facility until the arrival of the AI representative and the VAFB fire department.
- 2) If the fire is located in the low bay area, an attempt will be made by the guard to minimize fire damage prior to the arrival of the VAFB fire department.
- 3) If the magnitude of the fire is so great that control is impossible, impractical, or hazardous, the responsible AI representative will be called and the guard will retreat with the emergency kit to the EAA and restrict entry into the facility until the arrival of the AI representative and the VAFB fire department.

In the event the guard discovers a fire which has not activated the fire alarm, he will activate the alarm manually by breaking the glass in the face of the alarm box before initiating any other efforts.

If the radiation alarm is activated while the guard is engaged in fighting a fire, he will immediately cease his fire-fighting efforts, retreat to the EAA with the emergency kit and restrict entry into the facility.

In all cases, the AI Base Manager, upon notification of the emergency, will be responsible for notifying the AEC Base Representative.

The VAFB fire department, upon arrival, will engage in fire fighting, if the radiation alarm system has not been activated. If the radiation alarm system has been activated, no entry will be made until arrival of the AI representative. The VAFB fire department will be instructed in methods of fighting a NaK fire with the Met-L-X extinguishers and dry calcium carbonate containers provided in the high bay area. Further instructions will be given that no water is to be applied in the high bay area; however, fires in the office area may be fought in a conventional manner provided the amount of water used will not cause flooding into the high bay area. In the high bay area portable CO₂ extinguishers are provided for fighting fires which do not involve NaK. The use of large hoses will be restricted.

5. Radiation Alarm

a. Building Occupied

In the event the radiation alarm is activated, emergency evacuation procedures will be initiated. Upon receipt of the radiation alarm signal during hours when the SPTF is occupied, the VAFB Control Center will notify the 392 Aerospace Medical Group (392 AMG).

The SPTF supervisor or his designee shall have the following responsibilities: for terminating operations, assuring the test-log evacuation; ascertaining that all persons are present in the EAA or accounted for; and that the emergency kit is acquired from the guard station during evacuation.

b. Building Unoccupied

In the event the alarm system is activated during periods when the SPTF is unoccupied, the VAFB Control Center, upon receipt of the alarm signal, will notify the 392 AMG and call the responsible AI representative as indicated by the telephone numbers supplied them. The AI representative shall be responsible for notifying the AEC Base Representative. Upon activation of the alarm, the facility guard will retreat to a point on the access road adjacent to the EAA with the emergency kit, and restrict entry into the facility until arrival of the 392 AMG or the responsible AI official. The 392 AMG will further assess the situation and assist the guard in restricting the area. No reentry into the facility will be made until the AI representative declares the facility safe to enter.

6. Other Emergencies

Emergency procedures for earthquakes, floods, storms, etc., and for civil defense will be dictated by the overall VAFB emergency procedures and will be complemented by those special precautions necessary to the specific operations in the SPTF.

G. EMERGENCY PROTECTIVE EQUIPMENT

Six sets of emergency protective equipment will be maintained in an easily accessible location near the locker room and in the guard shack. The equipment will be of the quick donning type to permit its effective use in case of an emergency. The Supervisor will determine which pieces of protective equipment should be used by the operations personnel.

VI. SAFEGUARDS CONSIDERATIONS

A. GENERAL

The operations in the SPTF will be performed with proper safeguards and procedures to assure that the reactor will always be maintained in a subcritical condition. Normally, only one SNAP Unit will be under test and reassembly in the building. During this time, normally only one other SNAP Unit will be allowed in the building; it will be kept in its shipping container (Figure 27). This procedure precludes the possibility of a critical assembly occurring in the interaction of multiple reactor units. If it should become necessary to work on more than one SNAP Unit simultaneously, minimum safe separation of 12 ft between units will be observed as discussed in Appendix B. Because of the precautionary safeguards and the limited operations to be conducted, no significant radiological hazards are involved in the testing, assembly, and handling operations. However, there are certain accidents which could conceivably occur but none could credibly result in a nuclear incident. The potential nonnuclear hazards are associated primarily with the release of toxic materials into the atmosphere. A NaK fire in the vicinity of the core would be the prime cause of such hazards. This type of accident is considered to be the maximum credible accident for the SPTF. Such accidents, with the consequent release of hazardous materials, and the safeguards which are provided to prevent the occurrence of a nuclear accident, are discussed in this section.

1. Operations Summary

The only significant operation involving reactivity changes is in the installation of the reflector assembly. This operation is accomplished by using a controlled interlock procedure. The shipping sleeve will be replaced with the reflector assembly which is equipped with void filler blocks and locking arms. These safeguards remain in place throughout all remaining SPTF operations, restricting environmental reactivity additions and preventing drum movement. No liquid moderators will be piped into the high bay area of the SPTF. The available volume of hydrogenous liquid will be limited to 5 gal. As a result of these safety devices and other safeguards procedures, a nuclear excursion in SPTF is deemed noncredible.

Figure 27. SNAP 10A Power Unit Systems Storage Control in the SPTF

2. NaK Experience

Atomics International's experience in handling NaK as a reactor coolant began in the fall of 1959 when the SNAP Experimental Reactor (SER) was first filled with coolant.

In those few instances where NaK fires have occurred, the fire has either been quickly extinguished or intentionally allowed to burn out harmlessly.

3. Reactor Experience

The SNAP 10A/2 reactor is similar in design to reactors which have been developed by, or are presently being operated by, AI for the AEC. The SER has been extensively tested and its nuclear characteristics determined. After 6000 hr at critical, the SER was disassembled and replaced by the SNAP Developmental Reactor (S2DR). The S2DR has completed a 21-mo test program during which it was operated for 48 days at 1200°F. These two reactors, along with the original critical experiments, have provided a great deal of experimental information regarding the nuclear characteristics of these systems.

4. Prior SNAP Unit Test History

Prior to shipment to VAFB, the SNAP Unit will undergo nuclear and thermal acceptance testing at Santa Susana. During this time only zero power tests will be performed, which are defined as tests in which the power level range is up to four orders of magnitude above source critical. With a neutron source emitting 10^7 n/sec (5 curie Pu-Be), the reactor power would be in the order of 10 watts.

B. NON-NUCLEAR CONSIDERATIONS

Because of the reactive characteristics of NaK, the exposure of NaK to air is a potential fire hazard. Small NaK fires are not difficult to contain if special fire-fighting equipment and procedures are used for handling them. NaK fires occur only in the presence of air, water, or oxidizing chemical compounds. Since the NaK in the SNAP Unit is filled and sealed prior to shipment to the SPTF, the probability of a NaK fire is small. However, the possibility of an accidental fire occurring in the high bay of SPTF and consequently releasing hazardous materials to the environment does exist.⁴ This type of accident is considered to be the maximum credible accident and is discussed in this section.

1. Hazardous Materials

The hazardous materials which are associated with the SNAP 10A Unit are as follows:

- a) NaK
- b) LiH
- c) Beryllium vapor and beryllium oxide
- d) Uranium
- e) Residual radioactive fission products

The presence of NaK and LiH is not considered to be as potentially dangerous as the other above listed materials. Although NaK and LiH materials may burn and become airborne as caustic fumes, they are chemical irritants only and are easily detected by their acrid odor and dense clouds of white smoke long before their concentrations reach maximum permissible limits.

2. Controls

In the event of a NaK fire, the high bay area will provide some confinement but not total containment of the toxic materials. If a fire occurs, the high bay ventilation system will be shut down manually by the supervisor using the master control switch (located near the front entrance to the low bay area) to inhibit the spread of these materials to adjacent areas. Also, the ventilation systems in the low bay area are always operated at a higher air pressure than those in the high bay system. The spring-loaded relief damper in the high bay roof will close, confining the toxic materials to the high bay. Emergency action will be put in effect and the building evacuated if dangerous concentrations of toxic fumes result from the accident. Provisions will be made in the handling and temporary storage of the NaK coolant in the building to prevent accidental spills. In addition, no liquids will be piped into the high bay area.

3. Maximum Credible Accident

a. Nature of Accident

The maximum credible accident is considered to be a NaK fire in the high bay area at a time when the SNAP Unit is out of the shipping container. The accident considered is a major NaK leak in the vicinity of the core and subsequent ignition.

b. Consequences Considered

(1) NaK Fire

The principal reaction products resulting from combustion of NaK are sodium monoxides and peroxides and potassium superoxide. The reaction is characterized by very low flames and dense clouds of white oxide smoke. Once started, enough heat is liberated to maintain the reaction which could gradually raise the temperature of the molten liquid to a maximum of 1436°F (bp of NaK). Equilibrium temperatures are expected to be somewhat lower based on the fact that the maximum temperatures of sodium burning in an open atmosphere have been measured and were found to be near 1200°F.⁵

The flame of a NaK fire is very low. Therefore, in the event that a NaK fire does start, it should be extinguished within a short period of time. Met-L-X (sodium chloride) is the most effective extinguisher because sodium chloride fuses at approximately 1200°F and forms a crust which floats on the surface of the NaK.

The toxic hazard resulting from fires involving NaK is in the formation of airborne alkali vapors of sodium and potassium oxides. The maximum amount of sodium and potassium oxides that may become airborne will be ~52 lb since the total NaK in the power system amounts to only 29 lb. This amount could burn for as long as 1/2 hr, assuming a minimum puddle diameter of 3 ft, if no attempt were made to extinguish it.

The high bay area will be evacuated immediately in the event of a NaK fire. Fire fighters will require proper protective equipment and self-contained breathing apparatus which will be conveniently located in the corridor outside the high bay and in the guard shack.

(2) Lithium Hydride Fire

Lithium hydride is the most abundant of the potentially hazardous materials in the power system. A total of 181 lb of this material is enclosed in a stainless steel casing which forms the radiation shield. Powdered LiH has a very low ($25 \mu\text{g}/\text{m}^3$) airborne MAC because it absorbs water from the lung tissue to form LiOH.⁶ However, potential airborne releases of LiH are negligible since the shield material is in bulk form and reactions with air and water vapor occur very quickly, especially at the fire temperatures of concern. Thus, any airborne release from a potential accident will probably involve lithium hydroxide

Figure 28. Beryllium Air Concentration vs Be Metal Temperature

Assuming an accident of sufficient violence to rupture the stainless steel casing and to break the LiH into small pieces, the LiH could be ignited by a NaK fire. Sufficient contaminants (LiOH , Li_2O_2 , and Li_2O) could be released to grossly exceed the MAC. An accident of this type is considered to be extremely unlikely because of the procedural controls in the SPTF. However, in the event of a NaK fire, the high bay area would be evacuated long before any significant release of LiH contaminants could possibly occur. Only trained fire fighters with proper protective equipment, including self-contained breathing apparatus, would be allowed to enter the accident area.

(3) Beryllium Involvement

The temperatures to which the beryllium could conceivably be exposed in the NaK fire could not possibly result in a significant airborne release of Be or BeO .³ Figure 28 indicates the temperatures required to produce equilibrium values of the concentrations that could occur in the high bay area.

(LiOH) or lithium monoxide (Li_2O) and dioxide (Li_2O_2) vapors and these are chemical irritants only, with a maximum acceptable concentration (MAC) identical to that of sodium and potassium oxides (2 mg/m^3).⁶

Experiments to determine the ignition temperature, rate of moisture pickup, and outgassing of solid cold-pressed lithium hydride in different environments have been completed.⁷ The observation that the ignition temperature of solid cold-pressed LiH in static air, although not definitely established, was lower than 750°F is of particular interest. Increased air flow tends to decrease the ignition temperature. Once ignited, temperatures as low as 500°F have been observed to support combustion.

(4) Fission Product Air Concentration

The maximum possible temperature of a NaK fire is not high enough to cause cladding rupture to the fuel elements, as shown in Figure 29. A mechanical method for rupturing the fuel elements would have to be postulated in order to release any volatile uranium or fission product activity generated during the zero-power acceptance tests at Santa Susana. As will be shown, even this incredible accident would not pose a major problem.

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Figure 29. Cladding Rupture Conditions

The core fission product inventory resulting from the "zero" power test is shown below:

Total Curies	Volatile (Xe, Kr, I, Br) Activity Curies
1.0×10^{-2}	2.4×10^{-3}

The above values assume: (a) a "zero" power acceptance test consists of operating the reactor for a period of 1 hr at a power level of 16 watts (or equivalent), and (b) a 2-wk interval has occurred between the end of acceptance tests and delivery of the SNAP Unit to SPTF. Further, it is conservatively assumed that all

the volatile (including iodine) activity is released into the high bay area — a total volume of $\sim 2800 \text{ m}^3$. The concentration of volatile material (Xe and Kr) in the high bay area is $3.3 \times 10^{-7} \mu\text{c/cc}$ (which is less than the MPC for a 40-hr wk). The I^{131} concentration is $\sim 1.14 \times 10^{-7} \mu\text{c/cc}$. Assuming a breathing rate of 347 cc/sec and a dose to the thyroid of 1.46 rem/ μc inhaled,⁸ the total dose per min of exposure is,

$$D_T = 1.14 \times 10^{-7} \mu\text{c/cc} \times 2.08 \times 10^4 \text{ cc} \times 1.46 \text{ rem}/\mu\text{c} = 3.46 \times 10^{-3} \text{ rem/min}$$

or, for a 30-min exposure, 104 mrem. These values are acceptable since exposure would not be for more than 30 min.

(5) Uranium Air Concentration

The specific activity of the uranium in the reactor is 64 $\mu\text{c/gm}$. This is based on 326 mc of U^{234} and U^{235} in a total of 5 kg of fuel. Contribution from other uranium isotopes is negligible. The analysis assumes that the partial pressure of uranium in the room (as calculated using Dalton's law) is equal to the vapor pressure of the uranium at 1436°F (the temperature of the NaK fire). The specific activity of the uranium in the air is calculated to be a factor of over 10^4 lower than the MPC for uranium in air of $1 \times 10^{-10} \mu\text{c/cc}$ for a 40-hr wk in a controlled area. This analysis is predicated on two reasonable assumptions:

- a) A cladding rupture does not constitute a complete loss of cladding around the fuel.
- b) The continuous release of hydrogen through the fissure or crack in the cladding will preclude any significant direct oxidation of uranium into UO_2 and the possible airborne release of particulates.

c. Preventive Measures

Under normal conditions, it will not be necessary to handle NaK in the SPTF as the SNAP Unit will be loaded and sealed before it is delivered to the facility. However, under certain circumstances, it may be necessary to drain NaK from the system in the event of a NaK leak (Section IV-H). In addition to draining the NaK from the system, the system will be purged with an inert gas.

The actual draining of the coolant from the SNAP Unit will be performed carefully and in strict accordance with NaK handling procedures. Proper fire-fighting equipment will be on hand at all times.

d. Conclusions

As indicated from the above discussion, none of the accidents considered present any serious hazards to personnel. For beryllium, there will be no significant airborne release of Be or BeO. In the event of a NaK fire the high bay will be evacuated immediately and fire fighters will wear required protective equipment. Although LiH contaminants are unlikely to occur, they would not be a problem since self-contained breathing apparatus will be worn. The maximum concentration of volatile fission products (Xe and Kr) and I^{131} are 3.3×10^{-7} and $1.14 \times 10^{-7} \mu\text{c/cc}$ respectively. These values are within the acceptable limits. The release of toxic materials in the event of an accident in the SPTF would not present a hazardous situation to surrounding areas.

C. NUCLEAR CONSIDERATIONS

1. General

There are several factors that will contribute to the safe handling of the SNAP Unit at the SPTF. As stated in the previous section, only zero-power acceptance tests are being conducted on the reactor at Santa Susana. During these tests the reactor power will be limited to four orders of magnitude above source critical, or about 16 watts. The resultant fission product inventory from the tests will be relatively low, and the release of the volatile fission products does not constitute a radiological hazard. The only operation to be performed in the SPTF that will significantly change the reactivity of the reactor is the removal of the shipping sleeve and installation of the reflector assembly. This operation is under strict procedural and mechanical interlock control. Both before and after the reflector assembly is installed, the control drums are locked in the least reactive position by three independent safety mechanisms, as shown in Table I. This reactor configuration can only reach criticality by water replacing the NaK within the core together with water completely surrounding the reactor. Even though such a condition is inconceivable when the SNAP Unit is in SPTF, as an added safeguard water is restricted from the high bay area at all times. Therefore, for a nuclear accident to occur with the reflector assembly installed, three separate mechanical mechanisms would have

to be removed together with the energizing of the actuator circuitry before all four control drums could rotate to their most reactive position; alternately, the SNAP Unit NaK system would have to be replaced with water and the reactor immersed in water. That either of the above postulated series of accidents could occur, is not credible except due to deliberate sabotage.

The other reactor configuration to consider is the condition of the reactor vessel surrounded by the shipping sleeve. This is the configuration when the reactor arrives at SPTF in the shipping container. When the reactor is surrounded by the shipping sleeve, subcriticality is assured even with water in the core and water surrounding the core. The shipping sleeve half-sections are held in place by special bolts and are not removable except during the reflector assembly installation. This installation procedure is controlled to permit only half of the reactor to be bare at any time during the operation. The installation fixture is designed so that the complete assembly operation may be accomplished by one man and an assistant.

During the installation operation, adequate shutdown margin is provided for all possible configurations (Appendix C).

2. Fission Product Inventory

Acceptance testing of the SNAP 10A at Santa Susana requires reactor operation at low power levels. Fission product activity will be produced in the fuel at this time. There is still some activity present when the SNAP Unit is received at SPTF. The fission product inventories were calculated to determine the total activity at several cooling periods after shutdown. The beta influence function data reported in Reference 9 were used.

Normal Operation

The fission product inventory shown in Table III is that following normal zero-power operation. It is conservatively estimated that the integrated power during the zero-power test is about 16 watt-hr. The following table is based on a 1-hr operation at 16 watts.

TABLE III
FISSION PRODUCT INVENTORY

Cooling Time	Total Activity (Curies)
0	40
1 hr	4
2 wk	1.02×10^{-2}
1 mo	4.48×10^{-3}

3. Reflector Installation

A detailed description of the reflector assembly installation together with postulated accidents and safeguards is presented in Appendix C.

4. Nuclear Accident

Table I shows that the reactor assembly is subcritical for all possible configurations during reflector assembly installation. Strict procedural methods include a keyed-locking system, a rate limited installation fixture, and use of radiation monitoring instrumentation to establish reactivity of the reactor. Strict control on the number of personnel adjacent to the reactor will be maintained during this operation. Only one person is required to perform the reflector installation. The void filler blocks, locking arms, and locking pins hold the four control drums in the OUT position at all times after the installation. All these features preclude the accidental insertion of excessive reactivity into the system that could cause a nuclear accident. The facility design criteria specifically excludes the piping of water in the high bay area and provides for water drainage away from the building. Also, the reactor is located about 12 to 15 ft above floor level during all operations except when the SNAP Unit is in the shipping container. Therefore, it is not credible to consider the building could flood with water to submerge the reactor vessel.

When the SNAP Unit is in the assembly area, removable stanchions in the floor protect the SNAP Unit from inadvertent collision with mobile equipment.

The only possibilities of a nuclear accident are as follows:

- a) A deliberate willful act of sabotage altering the keyed sequential operation to give a bare reactor, or a bare reactor half, or the removal of void filler blocks with simultaneous immersion in water.

- b) A major leak in the reactor system after reflector assembly is installed with simultaneous immersion in water and water replacing the NaK within the reactor.

These accidents are not considered as credible accidents.

5. Conclusions

In summary, a nuclear accident at the SPTF is not credible in the usual sense since a planned act of sabotage would be required to achieve criticality in conjunction with water immersion of the core. The condition of water flooding the core is even more remote, as severe SNAP Unit damage would be required before water could replace the NaK in the core. Therefore, all the planned operations in the SNAP prelaunch test facility are safe, and present no undue hazardous situations to operating personnel or VAFB personnel.

REFERENCES

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2. "SNAP 10A Flight Tests Final Safeguards Report (Draft)," NAA-SR-MEMO-7774, November 1, 1963
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APPENDIX A

SITE

A. AREA DESCRIPTION

Vandenberg AFB is located in western Santa Barbara County of Southern California, 140 miles northwest of Los Angeles and 55 miles west-northwest of Santa Barbara. This area is semi-arid and mountainous, with numerous canyons extending westward and southward from the Santa Ynez mountains to the ocean. The circled areas, Figure 30, show the relative position of the surrounding cities to the SPTF.

The Santa Ynez River basin is the major watershed. Its coastal plain and foothill area occupies about 380 square miles. The lower reaches of the river basin include the broad, flat Lompoc Valley that extends 13 miles inland from the coast. The agricultural uses of these areas and their hydrologic features are the principal factors to be considered in the disposal of toxic and radiological materials that might be accidentally released.

1. Topography

The topography in the vicinity of the SPTF consists of seaward-sloping hillsides and ravines that run to the ocean and to the Santa Ynez Valley. The highest mountain peaks in the area are to the south of the Santa Ynez Valley and are 1500 to 2170 ft in elevation. The latter is the elevation of El Tranquillon Mountain. The Santa Ynez River Valley runs westward to the ocean, 2 miles south of the SPTF site. The valley width at this point is 5 miles wide and 200 ft below the SPTF site elevation. The major drainage is via the Santa Ynez River Valley.

B. METEOROLOGY

A general index of the climate of the area is the length of the growing season which, in Lompoc Valley, averages 270 days. About 70% of the annual precipitation occurs during the 4-month period from December to March. During the 41 years of record, the annual rainfall at Lompoc has ranged from 5.96 to 40.58 in. and has averaged 14.44 in. In general, the coastal climate is characteristically mild and uniform throughout the year. The average annual temperature ranges from about 50° to 60° F. Temperatures below freezing or above 90°F seldom occur. During summer, nightly fogs and daily inshore sea breezes prevail.

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Figure 30. Location of SNAP Prelaunch Test Facility

1. Weather

The general area has a changing meteorological pattern closely related to the ocean currents and the continental climate and topography. Characteristic clouds, fogs, rainfall, and humidity will also influence the disposal of waste products.

Surface wind directions in the area are predominantly south to southwest along the coastline. Surface wind speeds vary markedly with location and season, being highest during the months of April, May, and June. Strongest wind speeds occur in winter. Superimposed on this large-scale coastal flow are the small-scale but highly important land-sea breezes with their daily reversal of direction.

a. Subtropical Temperature Inversion

The subtropical temperature inversion layer over the area is particularly low. It stems from contact of the surface or marine layer of moist air, cooled by the ocean, with adiabatically heated dry air above. The latter is the subsiding layer resulting from diverging wind circulation and the sinking of air around the semipermanent northeastern Pacific high-pressure cell to the west of California. Water evaporated from the ocean surface rises and is uniformly distributed to the interface between the marine layer and the subsiding layer. The resulting inversion layer inhibits vertical mixing. The horizontal movement of the marine layer is affected by the alternating land and sea breezes associated with canyon winds. The inversion is most frequent and undisturbed in summer when it is present essentially 100% of the time along the California coast.

It appears that air movement under the inversion can be expected to be sluggish and onshore during the summer. Superimposed on the seasonal wind is the land-sea breeze with its daily reversal of direction. Thus, there will be periods when the sea breeze in phase with the seasonal onshore wind gives a fairly strong resultant wind, which will tend to carry pollutants inland with resultant mixing in greater volumes of air. However, there will also be periods where the two winds, land breeze and seasonal wind, being out of phase, will cause periods of general stagnation, as in the early morning hours. When there is no wind, conditions exist favoring the accumulation of pollutants.

It may be expected that the area provides the meteorological climate favorable to the accumulation of toxic materials. Inversion characteristics that can be used to determine the concentration of radioactivity in the marine layer are height, temperature lapse rate, low-level wind speed and direction, and humidity.

C. POPULATION

Santa Barbara County, exclusive of the military bases, has an area where large in-migration of population has occurred, especially in the last decade (55,000 population increase).

From a 41,000 figure in 1920, the population expanded slowly to 98,000 in 1950, but surged to 168,000 in 1960.

The Lompoc region (Figure 31) is of particular interest. Of the 17,073 people and 5,787 houses in this area, all but 2,764 people and 936 houses are located in the city proper; the remainder are located mostly north and east of the town. Few of the civilian population (less than 100) live in the Santa Ynez Valley west of Lompoc. The military base population is about 11,000. This includes both VAFB and NMFFA. The main areas occupied by the general public are the city of Lompoc, 6 miles from the SPTF, population 14,309 (4000 people/sq mile); the area northeast of the city, population 12,888; and the few people on the farmland west of the city. The remainder of the area has a population density of about 3 people/sq mile. The beach area of Surf, California is occasionally occupied by railway employees. It is emptied of civilian personnel during missile launches, if required.

D. COMMERCIAL ACTIVITIES

Public activities in the area are mainly agriculture, surface mining, fishing, shipping, and the typical small town business of the city of Lompoc. The Santa Ynez Valley widens as it rises from the ocean to about two miles just south of the SPTF. The valley is used primarily for seed production, the principal producers are: Bodger Seeds Limited, Burpee Atlee, and Enholm Seed.

The industry of particular interest is the mining of diatomaceous earth by the Johns-Manville and Great Lakes Carbon Corporations. These concerns usually employ less than one thousand persons. The mining operations are shielded from the Pacific Missile Range (PMR) by mountains.

A main line of the Southern Pacific Railroad runs along the coast through both the NMFFA and VAFB. A spur turns off between the Naval Missile Facility at Point Arguello and Vandenberg AFB. Arrangements between the railroad and the PMR regulate traffic during danger periods in missile operations.

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Figure 31. Population Increase in Lompoc Area - 10 Year Increments

Shipping operations and fishing along the coast are controlled as required by the Navy and the Coast Guard. The Coast Guard's Marine Inspection Office at Long Beach issues a weekly "Local Notice to Mariners" advising them of activities in the area. Pleasure craft are advised to avoid the area because of weather and PMR operations. The Coast Guard Commander in San Francisco issues instructions for large areas such as the entire west coast. The beach is fenced off and not used by the public.

Air traffic is prohibited in the area by the "Regulations of the Administrator of the Federal Aviation Agency," Part 608. Regulation 2515 applies to VAFB and 2516 to the NMFPA.

E. POPULATION DENSITY AT THE VAFB

Population of the military base is approximately 11,000. The SPTF has been located so that no other building or road is closer than 800 ft. Population of this area will be limited to only those concerned with the operation of the SPTF.

F. CONCLUSION

The location of the SPTF is such that operations in the facility do not constitute a significant safety hazard to operating personnel or to surrounding occupied areas.

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2. "Geology and Water Resources of the Santa Ynez River Basin, Santa Barbara County, California," U. S. Geological Survey Water Supply, Paper 1107 (1951)
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APPENDIX B

MULTIPLE REACTORS IN FACILITY

A. GENERAL

The SNAP operations in the SPTF may require that more than one reactor be present in the building at any given time. This fact presents the problem of maintaining the minimum, safe, separation distance between reactors. In general, the available data for determining the minimum spacing between units of fissionable material are not directly applicable to assembled reactor systems. The k_{eff} of a single unit is usually larger than those given in the safety guides for single units.¹ Criteria are required, therefore, to establish the minimum separations between units for which the interaction will be negligible.

B. INTERACTION

A number of methods have been developed or are in the process of being developed² to solve problems of neutron interaction. One such method^{3,4} utilizes the k_{eff} of an individual unit in determining the maximum allowable solid angle between the central unit in an array and all other units. The method has been checked against experiments with highly enriched uranium solutions, as well as with highly enriched uranium metal systems, and the method found to give good agreement with these experiments. In applying this method to storage and transportation problems, it is recommended that it be used only for cases where the k_{eff} is ≤ 0.80 . Experimental data or values reduced from such data should be used for cases where $k_{eff} > 0.80$. This applies to the reactivity of the assembled cores under study.

Experimental interaction data having a $k_{eff} > 0.80$ have been made but the results are not available. Experimental interaction data for cylinders containing a high enrichment U^{235} in solution ($k_{eff} = 0.96$) are available.³ These data indicate that the critical solid angle between two bare 8-in.-diameter cylinders filled with solution having this reactivity is about 1.9 steradians. The critical solid angle is reduced to about 0.25 steradian when two, 20-in.-diameter cylinders are filled with solution to a height such that the $k_{eff} = 0.96$. Because there are no experimental data directly applicable to the problem at hand, it is necessary to have a separation between assemblies which permits interaction to be neglected. In the application of the solid-angle principle to nuclear safety

criteria, it has been suggested that interaction between any two units in an array may be neglected if the interaction solid angle contribution is less than 0.04% of 4π (0.005 steradian).

C. CONCLUSIONS

This criterion has been used to establish the minimum safe separation distance between any number of assembled cores of SNAP 10A units. For a core diameter of 9 in., and a height of 12 in., the minimum separation for a negligible interaction will be 12 ft. Separation of individual cores by at least 12 in. of concrete will also be adequate for isolation.

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APPENDIX C

NUCLEAR SAFETY DURING OPERATIONS AT THE SPTF

A. REACTIVITY VALUES RELATIVE TO REFLECTOR INSTALLATION, REMOVAL, AND NaK DRAIN

This section presents a review of the two major operations to be performed with the SNAP Unit at SPTF in which hazards are involved. A hazards analysis of these operations is included. These studies are included as supplementary information to the discussion on nuclear and non-nuclear accidents. Reactivity values presented in this section are based on published data from the SCA-4-C experiments and calculations that have been experimentally verified during the SCA-4-B experiments. All values are considered to be on the conservative side.

1. Reflector Installation and Removal

Objectives: Install or remove reflector assembly on the fueled reactor at the SPTF.

Initial Conditions

- a) Reflector Assembly Installation. Both halves of shipping sleeve are in place around the core. Void-filler blocks and locking devices on reflector assembly are holding drums in their least reactive position.
- b) Reflector Assembly Removal. Both reflector assembly halves are installed on the core. Void filler blocks and locking devices are holding drums in their least reactive position.
- c) Operation takes place with the SNAP Unit mounted on the vertical support stand located on floor of high bay.

Reflector Installation

- a) With shipping sleeve in place on both sides of the core, the shutdown margin is \$18.00.
- b) Install reflector assembly installation fixture. During this step, the reactivity worth of a single human body reflection adjacent to the core is estimated to be \$0.30. Therefore, shutdown margin is \$17.70, with shipping sleeve in place with a single human body standing adjacent.

- c) Remove one-half of shipping sleeve with one side of the core bare. The shutdown margin is \$19.10. The reactivity worth of a single human body standing adjacent to the core is estimated to be \$1.10. Therefore, the shutdown margin is \$19.10 less \$1.10 or \$18.00, with one human standing adjacent to the bare side.
- d) Install reflector assembly half with attached void filler block on the bare side of the core. The shutdown margin is \$11.30. The reactivity worth of a single human body standing adjacent in this case is estimated to be \$0.30. Therefore, the shutdown margin is \$11.30 less \$0.30, or \$11.00.
- e) Remove other half of shipping sleeve, leaving one-half of the reactor bare with the reflector assembly on the other half. The shutdown margin is \$12.40. The reactivity worth of a single human standing adjacent to the bare side of the core is estimated to be \$1.10. Therefore, the shutdown margin is \$11.30.
- f) Install other reflector assembly half with attached void filler block on the bare side of the core. The shutdown margin is \$4.60. The reactivity worth of a single human adjacent to the core with reflector assembly installed with void fillers is estimated to be \$0.30. This gives a shutdown margin of \$4.60 less \$0.30, or \$4.30.

Reflector Assembly Removal

- a) With the reflector assembly on both sides of reactor with void filler blocks installed, the shutdown margin is \$4.60.
- b) Install reflector installation fixture. During this step, the reactivity worth of a single human is estimated to be \$0.30. The shutdown margin is \$4.60 less \$0.30, or \$4.30.
- c) Remove one-half of the reflector assembly with attached void filler block leaving one side of the core bare. The shutdown margin is \$12.40. The reactivity worth of a single human standing adjacent to the core is estimated to be \$1.10. Shutdown margin is \$12.40 less \$1.10, or \$11.30.

- d) Install shipping sleeve in place on the bare side of the core with reflector assembly on other side. The shutdown margin is \$11.30. The reactivity worth of a single human is \$0.30. The shutdown margin is \$11.30 less \$0.30, or \$11.00.
- e) Remove reflector half leaving one side of the core bare with shipping sleeve on other side. The shutdown margin is \$19.10. The reactivity worth of a single human standing adjacent to the bare core is estimated to be \$1.10. The shutdown margin is \$19.10 less \$1.10, or \$18.00 with one human standing adjacent to the bare side of the core.
- f) Install other half of shipping sleeve. The shutdown margin is \$18.00. The reactivity worth of a single human standing adjacent to the core under these conditions is estimated to be \$0.30. The shutdown margin is \$18.00 less \$0.30, or \$17.70.

Postulated Accident. During reflector assembly installation, the reflector installation fixture mechanically fails when the core is half bare and the reflector assembly is on the other half. The installation fixture is removed for repair and, prior to replacing the shipping sleeve, one of the operating personnel falls and the body is adjacent to the bare side of the core.

Consequences. As shown above, the reactivity changes from -\$12.40 to -\$11.30. Since the core is still subcritical with a $k_{\text{eff}} = 0.92$, there are no personnel hazards.

Safeguards to Prevent Postulated Accident. The reflector handling mechanism, when indexed to the core, prevents personnel access to the core. The reflector installation fixture is attached to the reflector halves using the void filler blocks. This interlocks the drums in the OUT position before they are installed or removed from the core. The sequence of operations is interlocked by the use of keys. This prevents the removal of both sides of the reflector or shipping sleeve leaving both sides of the core bare.

Each step in the operation will be controlled administratively by the use of checkoff sheets.

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2. NaK Drain

Objectives

- a) Drain NaK from the fully fueled SNAP Unit reactor and associated piping system and purge with inert gas after detecting a system leak at the SPTF.
- b) Seal NaK fill lines and drain.

Initial Conditions

- a) The SNAP Unit mounted on vertical support stand in high bay.
- b) NaK fill lines hooked up to SNAP Unit at fill connections.
- c) Shipping sleeve in place on both sides of the reactor.

NaK Drain Procedure — When a leak develops, the following procedure applies:

- a) Ascertain to the degree possible the fire hazard present, having made available fire fighting and personnel protective equipment.
- b) Allow the NaK to drip into a pan containing dry calcium carbonate. Orient the SNAP Unit to minimize the damage and to obtain the most favorable position to direct the drip into the container.
- c) Place the Unit on the work platform after drip has stopped.
- d) Freeze a section of the fill line using dry ice and with a pipe cutter cut off an inch of fill pipe.
- e) Connect Tygon tubing to fill line. Other end will be connected to pressure regulated (3 psi) argon supply.
- f) Open the drain line using technique of step d).
- g) Connect drain line to stainless steel container.
- h) After NaK has been drained, purge system with argon.
- i) Seal off fill and drain lines with clamp in section of Tygon tubing.
- j) Place Unit in the shipping container in an argon atmosphere.
- k) Return Unit to Santa Susana for leak repairs.

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Reactor Status During This Operation

- a) The reactor shipping sleeve is in place on the reactor, providing a shutdown margin of \$18.00 prior to NaK draining.
- b) The worth of the NaK in the core has been calculated to be less than 1¢. Therefore, the shutdown margin is virtually unchanged.
- c) After the NaK drain, the system NaK lines are sealed off. During this operation, the reactivity worth of a single human is \$0.30, leaving a shutdown margin of \$17.70.

Postulated Accident. As shown under the reactor status, the shutdown margin is \$17.70, so no nuclear accidents are postulated.

During NaK drain and the NaK tube sealing operations, it is possible for a NaK leak to occur at the fill connections. For this operation the NaK leakage would be directed into containers above the reactor where it would burn. This burning does not occur in the vicinity of the core and consequently no fission products will be released.

Consequences of the Postulated Accidents. A NaK fire occurs with no undue hazards to personnel.

Safeguards. Containers and shield covers will be provided to protect the SNAP Unit in the event of a NaK leak during the draining and sealing operations. Dry calcium carbonate will be placed in the containers and all personnel will wear the required protective clothing.

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