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SNAP 10A Power System Shipment Safeguards Report

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SNAP 10A POWER SYSTEM SHIPMENT
SAFEGUARDS REPORT

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.

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Editor

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A DIVISION OF NORTH AMERICAN AVIATION, INC.
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1. ABSTRACT

As a part of the operations required in the joint Atomic Energy Commission-US Air Force SNAP 10A Flight Test Program,¹ it is planned to ship at least two, and possibly three, SNAP 10A power systems² by escorted trucks from: (1) the Santa Susana Field Test Laboratories of Atomics International to Vandenberg Air Force Base (VAFB) and (2) VAFB to the Naval Missile Facility, Point Arguello (NMFPA). Following acceptance testing at the Santa Susana facility, the power system is prepared for shipment by removing the beryllium reflector from the assembled reactor unit and placing a special "shipping sleeve" around the reactor core vessel. This assembly is then placed in a double-walled shipping container, and loaded onto a truck. Shipment then proceeds under controlled conditions to the SNAP Pre-launch Test Facility (SPTF)⁴ located on VAFB. Following certain nonnuclear operations at this facility, the power system is reassembled, returned to the shipping container and transported by escorted truck to the designated launch complex at Point Arguello. The safeguards against potential accidents provided during these shipments and an evaluation of the potential consequences of those accidents considered as the maximum credible in each phase are delineated. On the basis of these analyses it is concluded that the shipments, as described, pose no significant hazard to either operating personnel or the public.

2. INTRODUCTION

2.1 PURPOSE AND SCOPE

This report describes the procedures and safeguards provided for transporting the SNAP 10A power system from the manufacturer's facility (Santa Susana Field Test Laboratories, Atomics International) to the launch site, Naval Missile Facility, Point Arguello (NMFPA). Control of any potential hazards will be effected to allow successful completion of this phase without significant risks to operating personnel or to the general public. The report is intended for use by safety review and approval agencies within the US Atomic Energy Commission, the US Air Force and the US Navy Pacific Missile Range.

The report scope includes shipment of the reactor system from the Santa Susana Facility to the SNAP Pre-launch Test Facility (SPTF) at VAFB and from the latter facility to Point Arguello Launch Complex No. 2 (PALC-2) at the NMFPA. The safety aspects of other phases of the program appear in other reports.^{1,3,4} A detailed description of the power system and an overall summary of the factory-to-flight sequence is presented in reference 2.

2.2 PROGRAM DESCRIPTION AND OBJECTIVES

The joint USAF-AEC SNAP 2/10A Flight Tests Program is a companion to the AEC SNAP Development Program. It is the purpose of these flight tests to proof-test, under actual ascent and orbital conditions, two specific nuclear auxiliary space power systems, SNAP 10A and SNAP 2.

In optimizing the utility of these systems, the ease and safety with which the units can be handled prior to launch is of great importance. The present plan of complete assembly and nuclear testing prior to leaving the manufacturer removes the problem of providing a nuclear facility at the launch site. However, the shipment of a fully fuel-loaded reactor necessitates a more extensive analysis of the shipment and the safeguards necessary for the protection of the system and of the public. The present plan for the shipment of the system represents an optimization of both operational and safety considerations.

3. SUMMARY OF RESULTS AND CONCLUSIONS

For purposes of safety analysis, the proposed shipment of the SNAP 10A power systems is conveniently divided into two phases: (1) from the Santa Susana Field Test Laboratories of Atomics International located near Canoga Park, California to Vandenberg Air Force Base located near Santa Maria, California and (2), from Vandenberg Air Force Base to the adjoining Naval Missile Facility at Point Arguello.

3.1 SANTA SUSANA TO VANDENBERG AIR FORCE BASE (VAFB)

Prior to shipment to VAFB, the SNAP 10A power system will be subjected to mechanical, electrical and nuclear acceptance testing at Building 019, Santa Susana.³ Nuclear tests will result in a total of approximately 16 watt-hr of operation and thus create a relatively small fission product inventory. Approximately two weeks will be required to prepare the power system for shipment following completion of these tests. At the end of this two week period, the fission products in the reactor will total less than 10 mc and will result in a dose rate of approximately 5 mr/hr, 1 ft from the reactor vessel.¹⁹

For the transport from Santa Susana to VAFB, the beryllium reflector halves are removed from their position around the reactor vessel and the reactor core is enclosed in a specially designed shipping sleeve. The shipping sleeve assures the maintenance of reactor subcriticality under the extreme condition of complete submergence of the reactor, including internal replacement of the NaK coolant, in a hydrogenous fluid such as water.

The power system will be enclosed in a double-walled shipping container, with the inner container shock-mounted to minimize normal transportation forces. This inner container is also airtight to permit the maintenance of an argon atmosphere around the reactor. The argon atmosphere will prevent a coolant (NaK) fire from occurring should a leak develop in the coolant piping during shipment.

A flatbed truck, escorted by two vehicles carrying security police, ground handling personnel, health physicists, and AEC representatives, will transport the power system, the separately packaged lithium hydride (LiH) radiation shield, the beryllium reflector halves, and continuously functioning monitoring equipment. The route of transport selected follows US Highway 101

north along the coast to Highway 1, then to VAFB, a total of 150 miles. According to data of the California Division of Highways, the probability along this route of an accident involving a truck was about 1×10^{-7} accidents per truck mile during the years 1958 to 1960, or a total of 1.5×10^{-5} for the entire trip.

The maximum credible accident is postulated as a collision between the transport vehicle and a gasoline truck. Although a collision with a truck carrying some other inflammables and oxidizers might produce a more intense fire, the probability of such a collision, due to the limited number of these trucks, is so small that it cannot be considered as the maximum credible accident. While a collision with a gasoline truck could cause a fire which could conceivably consume the LiH radiation shield and the NaK coolant, and cause some oxidation of the Be reflectors, a nuclear incident would not result. The protection afforded the fuel elements by their cladding, and the very low inventory of fission products present, would prevent any significant airborne hazard from either the uranium or the included fission products. Thus, it is concluded that the safeguards provided during this phase of the shipment, both procedural and design, adequately protect the general public and the operational personnel from significant hazards.

3.2 VANDENBERG AIR FORCE BASE TO NAVY MISSILE FACILITY, POINT ARGUELLO

Following the necessary operations at the SPTF, and about 2 wk prior to the scheduled launch date, the power system will be replaced in its shipping container for shipment to PALC-2, NMFPA. The shipping sleeve will not be utilized for this phase, since the reflector, void-filler block combination will be mounted on the core. In this condition, subcriticality of the reactor is assured under all types of environmental influences (including complete water reflection) with the exception of internal water flooding. The route covers about 10-1/2 miles, of which all but approximately 2 miles is on military property. Complete traffic control will be effected over the entire route during the shipment. Except for the substitution of the reflector, void-filler block combination for the shipping sleeve and the addition of the radiation shield to the power system, the transportation mode is the same as that discussed in the previous phase.

Because of complete traffic control, the maximum credible accident during this phase of shipment is evaluated as a single truck accident which results in a rupture of the power system piping and causes ignition of the NaK coolant (~29 lb). No nuclear material would be involved and the consequences of this accident would present a negligible hazard to either operating personnel or to the environs.

4. SAFETY ANALYSIS

4.1 SANTA SUSANA TO VANDENBERG AIR FORCE BASE

4.1.1 Preshipment Operations

Certain operations of importance which occur prior to shipment of the power system are presented below.

4.1.1.1 Acceptance Tests

Acceptance testing is divisible into two primary phases, nuclear and nonnuclear operations.

4.1.1.1.1 Nuclear Tests

Power system nuclear operations will be limited to criticality and zero-power experiments.³ The testing program will include control drum calibration and determinations of reactivity worths and temperature coefficients. The reflector and control drum shims will be adjusted, if required, to provide the desired excess reactivity for the system during orbital operation. Heat transfer and nuclear system integration characteristics will be determined by the application of electrical heat. Power levels during these tests will be in the order of 10 watts and will be limited to an increase of neutron count rate of four decades above the original criticality count rate. The reactor will not be operated at a constant power during these acceptance tests. The total integrated power, which will be spread over a week or two of time, will amount to about 16-watt hr although no significant hazard would result from exceeding this figure by as much as an order of magnitude. Figure 4-1 shows the calculated gross fission product activity and dose rate 1 ft from the reactor as a function of time after final reactor shutdown. These data are conservatively based upon constant power operation. Following the approximately two week period required for shipment preparations, the gross fission product activity will be less than 10 mc, and the dose rate at 1 ft approximately 5 mr/hr.¹⁹

4.1.1.1.2 Nonnuclear Tests

Nonnuclear testing to demonstrate heat transfer system characteristics under design conditions will be initiated upon satisfactory completion and acceptance of the nuclear tests. A minimal testing program to verify previously recorded experimental data is planned during final acceptance testing.

Figure 4-1. Fission Product Inventory and Dose Rates
Following Acceptance Testing

7561-1037

4.1.1.2 Ground Handling Equipment

The ground handling equipment used in preshipment operations is enumerated and described below.

4.1.1.2.1 Power System Handling Fixture

The power system handling fixture, Figure 4-2, is used to support and protect the power system as well as to provide pickup points for handling. This fixture provides protection for the external radiators on the surface of the power system cone and is used throughout all subsequent handling operations. The handling fixture is a conical-shaped unit 105 in. in height with a 64 in. diameter base. There are six vertical support members with four circular support rings. Eighteen removable panels are provided between the rings and the vertical support members. The handling fixture attaches to the power system at the upper and lower rings of the cone. The upper support points are at the upper torque ring of the power system cone structure and the lower support points are attached to the lower ring of the structure. Eight adjustable brackets on each of these rings hold the system in place. During shipment of the power system in the shipping container, an additional support point is added between the handling fixture and the power system at the shipping sleeve.

4.1.1.2.2 Tilt Sling

The tilt sling, Figure 4-2, is used to handle the power system in its handling fixture in either the horizontal or the vertical position by means of an overhead hoist and also to rotate the power system, in its handling fixture, from a vertical to a horizontal position, or the reverse. This rotation is necessary as portions of the checkout procedure require that the power system be in the vertical position while it must be in the horizontal position for shipping and/or mating checkout. The tilt sling consists of a triangular-shaped upper spreader bar with fixed length support cables at two of the corners. At the third corner there is a chain rope that is raised and/or lowered by means of an electric hoist. The fixed-length cables attach to the handling fixture above the center of gravity while the chain rope attaches below the center of gravity. By changing the length of the chain rope support, the power system and handling fixture are rotated into the horizontal or the vertical position. The chain hoist electric motor is equipped with a brake so that the power system may be held at any desired angle. When the power system is rotated to the horizontal position the extra chain rope is caught in a chain bucket mounted on the assembly and thus cannot damage the system.

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Figure 4-2. Power System Handling Fixture and Tilt Sling

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4.1.1.2.3 In-Plant Transporting Dolly

The in-plant transporting dolly is used to move the assembled power system within a building or from building to building. The dolly is not designed for highway use. This four-wheeled dolly has pneumatic tires, air bag suspension, shock absorbers, towbar and automotive knuckle-type steering, and is designed to support the power system in either the horizontal or the vertical position. The overall width is 82 in. and the overall length, with the towbar stowed, is 185 in. The dolly is towed by a tug, truck, or forklift.

4.1.1.2.4 Vertical Handling Yoke

The yoke provides a method of handling the power system vertically with an overhead hoist when the power system is not in the handling fixture. It has four arms which attach to the upper torque ring of the power system structure. The yoke provides for attachment to an overhead hoist.

4.1.1.2.5 Power System Vertical Support Stand

The support stand fixture, Figure 4-3, is used to vertically support the power system in its handling fixture and to allow access to both the interior and the exterior of the power system. The power system handling fixture base attaches to the upper plate of the vertical support fixture. This upper plate has a circular cutout large enough to permit access to the interior of the power system cone and to allow for installation of the shield.

4.1.1.2.6 Power System Shipping Container Sling

The power system shipping container sling utilizes an overhead hoist and provides a method for handling the inner and outer shipping containers. It is a yoke frame configuration, with four cables that attach to the shipping container, providing an overhead hoist pickup point.

4.1.1.2.7 Shield Handling Sling

The shield sling, Figure 4-4, provides a method for handling the LiH radiation shield with an overhead hoist. It consists of a yoke frame configuration with arms attached to the support ring adapter assembly. The sling has a slot in the center of the spreader bar for attachment to an overhead hoist.

4.1.1.2.8 Sling For Handling Radiation Shield Shipping Containers and Reflector Assembly Shipping Containers

This sling provides a method for handling these shipping containers with an overhead hoist and is a yoke frame configuration with arms attaching

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Figure 4-3. Power System Vertical Support Stand

12-26-61

7580-10140

Figure 4-4. Shield Handling Sling

NAA-SR-MEMO-8147

to the shipping container. The sling provides for attachment to an overhead hoist.

4.1.1.2.9 Reflector Handling Fixture

The reflector handling fixture provides a method of handling and transferring the reflector assembly from the reflector installation fixture to the shipping container adapter.

4.1.1.2.10 Heat Shield Handling Sling

The ejectable heat shield handling sling, with an overhead hoist, enables the removal of the heat shield from the power system. Due to the configuration of the heat shield, special handling equipment is required. The sling has a single support that attaches to the ejectable heat shield. A fitting is provided for an overhead hoist attachment.

4.1.1.2.11 Radiation Shield Installation Fixture

The radiation shield installation fixture, Figure 4-3, is used to hold and position the shield assembly during its installation or removal from the power system. The fixture consists of the following items:

- a) A hemispherical dish to support the shield,
- b) A three stage hydraulic cylinder (ram) to raise the shield,
- c) A hydraulic pump and reservoir unit to drive the ram, and
- d) A stand to hold the support dish and the shield when the shield is not on the power system or in its own shipping container.

4.1.1.2.12 Reflector Assembly Installation Fixture

This fixture, Figure 4-5, is used to install or remove the reflector assembly or shipping sleeve from the power system. Precise motion control of the reflector assembly is required during this operation. A number of safety features are incorporated into the design of the fixture:

- a) Removal or installation operations can be accomplished with only half of the reflector or sleeve at one time.
- b) Initiation of any removal operation can only proceed with the use of a special, controlled tool.
- c) The fixture will not accept the reflector unless the void filler blocks are in place.

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.

Figure 4-5. Reflector Installation Sequence

- d) Removal of the second reflector or sleeve half cannot proceed until the first sleeve or reflector half has been installed on the reactor.

More detailed information on the use of this fixture may be found in References 3 and 4.

4.1.1.3 Preparation for Shipment

After completion of the acceptance tests at Santa Susana, the power system is mounted upon the guide fixture (Figure 4-6). The handling fixture is lowered over the power system and secured to it with eight equally spaced bolts at the bottom and at the top of the fixture. The reactor projects above the handling fixture.

The radiation shield, Figure 4-7, is removed by the shield handling equipment and placed in the shield shipping container, Figure 4-8. Using the reflector handling fixture, Figure 4-5, the Be reflector assembly is removed from the reactor one-half at a time and placed in the reflector assembly shipping container, Figure 4-9. One-half of the shipping sleeve (see 4.1.2.1) is mounted on the reactor before the second half of the reflector is removed. The second part of the reflector is next removed from the reactor, placed in the shipping container with the first half, and the rest of the shipping sleeve secured to the reactor. The handling fixture cap is then placed over the reactor assembly and secured in place.

The power system, inside the handling fixture, is lifted by the tilt sling, rotated to the horizontal position, Figure 4-2, gently lowered into the bottom half of the power system shipping container and secured in place. Some of the monitoring equipment wiring is next attached to the power system and the leads connected to the plugs in the lower half of the shipping container. The upper half of the inner shipping container is set in place and secured with the quick disconnect fasteners. The upper half of the outer shipping container is mounted in place and secured.

The shipping container is pressurized with clean dry air to 3 ± 0.03 psig and left for one-half hour, at the end of which time the pressure is checked. If the pressure has not decreased more than 0.1 psig the shipping container is purged with argon and then pressurized with argon to 2.75 psig. Extra argon bottles are mounted on the outside of the shipping container.

12-6-62

Figure 4-6. Handling Fixture and Guide Fixture

7561-5201Ja

10-5-61

Figure 4-7. SNAP 10A Shield Assembly

7580-10113C

12-21-61

7580-18100-Q

View a

12-21-61

7580-18100-O

View b

12-21-61

7580-18100-A

View c

Figure 4-8. Shield Shipping Container

NAA-SR-MEMO-8147

HT. 44 IN.
DIA. 44 IN.
GR. WT. 300

REFLECTOR

REFLECTOR
SUPPORT

CONTAINER

SKIDS

11-28-61

7580-10136A

Figure 4-9. Reflector Assembly Shipping Container

The shipping container is loaded on the flat bed of the transport vehicle with an overhead crane and bolted in place. The monitoring equipment is mounted on the bed, and the connecting leads are attached to the plug on the shipping container. The reflector assembly shipping container and the radiation shield shipping container are mounted on the bed and secured in place. Following completion of the loading, the power system is ready for shipment to VAFB.

4.1.2 Shipment Operations

4.1.2.1 Shipment Container Description

The equipment used during shipment of the power system from Santa Susana to VAFB is described and listed below.

4.1.2.1.1 Reflector Assembly Shipping Container

The reflector assembly shipping container (Figure 4-8) is a light-weight, single-walled vessel used to enclose and protect the reflector control assembly during storage and/or shipment. Because of safety requirements, it is desirable to ship the reflector control unit in a container separate from that housing the power system. Provisions are included in the container for purging, if required. A humidity indicator, a desiccant chamber, a record storage chamber, and vibration isolation between the container and the inner support ring adapter assembly are included in the container.

4.1.2.1.2 LiH Shield Shipping Container

The shield shipping container is similar to that used for the reflector assembly and it encloses and protects the shield during storage and/or shipment. The shield is not in place on the power system during shipment to VAFB and it thus requires its own shipping and storage container.

4.1.2.1.3 Power System Shipping Container

The container is a double-walled vessel with provisions for purging and for maintaining an atmosphere of inert gas at a low positive pressure in the inner container. It is used to enclose and protect the power system during storage and shipment. The container holds the power system, in its handling fixture, in a horizontal position and is capable of containing the power system with either the shipping sleeve or reflector-void filler block combination. When housed in the shipping container, the power system is protected from damage from ordinary transportation shocks. A sealed inner container limits the shock load to the

power system to 2 g (for a 5g input). Shock and vibration isolation is provided between the inner and outer containers. The cylindrically shaped container is about 8 ft in diameter and 18 ft in length. Its approximate tare weight is 3000 lb. A more detailed description of this container is presented in 4.1.3.1.2.

4.1.2.2 Safety Equipment Description

The principal safety equipment used during shipment consists of; (1) the power system shipping sleeve and, (2) the power system shipping container monitoring equipment.

4.1.2.2.1 Power System Shipping Sleeve

The shipping sleeve is a specially designed nuclear protective device which insures the maintenance of reactor subcriticality under any credible environmental condition. The sleeve is composed of two sections which are placed in turn around the core vessel as the reflector halves are removed. Because of the importance of this device to the overall safeguards provided during the shipment, a detailed description is presented under Design Safeguards (4.1.3.1.1).

4.1.2.2.2 Power System Shipping Container Monitoring Equipment

This equipment, Figure 4-10, provides the means of adequately monitoring the environmental conditions of the power system whenever the power system is in place in the shipping container. The monitoring functions include:

- a) radiation (gamma)
- b) NaK leaks
- c) vibration and shock loads
- d) inert gas (argon) pressure changes
- e) temperature changes

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 radiation of the power system when it is outside of the shipping container. The equipment will consist of the following items:

Electric Power Plant.

This power plant will be driven by a gasoline engine and will be capable of delivering 2000 watts at 115-v, 60 cps and will contain sufficient fuel to operate

for at least 10 hr. The power plant will contain a 12-v starting battery which may also be used to supply the monitoring devices (less the recording equipment) for a period of 4 hr through a dc-to-ac inverter in case of malfunction of the power plant.

Instrumentation Cabinet

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

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

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

Display Panel - The display panel will contain the instruments and indicating lights displaying the monitored data. It will also contain the push buttons and switches for controlling the instrumentation.

Remote Display Panel - The remote display panel will be functionally similar to the display panel located in the instrumentation cabinet, except that it will be placed in the tractor cab. One or the other of the two display panels may be activated by means of a selector switch.

Sensors

The sensors will be mounted inside the inner shipping container, except for the gamma radiation detector probe, which will be mounted between the inner and outer containers.

Alarm Devices

Alarm devices (lights and/or buzzers) will be incorporated on certain of the environmental monitors at the display panel in the tractor cab. No external alarm devices will be in operation during transport. However, provisions will be made for attaching such external alarm devices to the monitoring system if desired at other times.

Figure 4-10 is a conceptual layout of the monitoring system as installed on the transport vehicle.

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Figure 4-10. Power System Monitoring Equipment

4.1.2.3 Transporting Vehicle Description

The power system will be transported from Santa Susana to VAFB by either a commercial or a military flatbed truck. The truck bed will be at least 8 ft wide and 35 ft long with a minimum load capacity of 5 ton.

4.1.2.4 Shipment Personnel

During transportation, the personnel utilized will be divided among three vehicles, which are the flatbed transport vehicle and two escort vehicles. The lead vehicle will contain the driver, AI security police, a health physicist, and AEC representatives. The truck will contain the driver and a technician who will maintain surveillance of the monitoring equipment and record excess g loading during transit. The trailing vehicle will contain the driver, AI security police, and ground handling personnel. Radio communication will be maintained between all three vehicles at all times.

4.1.2.5 Shipment Procedures

A detailed shipping procedure manual⁷ will be prepared and receive the necessary approvals prior to the shipment. This manual will contain specific instructions to be followed during transport, including emergency action in the event of accidents enroute. In general, however, the following principles will be employed:

- a) The approximately 6-hr trip will be scheduled for a period of minimum traffic, probably leaving Santa Susana between 10 and 12 PM and arriving at VAFB between 4 and 6 AM the following morning.
- b) The trip will not be scheduled with adverse weather existing or expected (i.e., rain, fog, high winds, etc).
- c) The maximum speed of the truck will be restricted to a safe value, probably resulting in an average of about 25 mph for the trip.
- d) One escort vehicle will precede the truck in order to give warning in the event of unexpected road hazards. The other escort vehicle will follow the truck.

4.1.2.6 Route Description

4.1.2.6.1 Possible Alternate Routes

The route chosen was selected as the best of four possible routes. This route follows US Highway 101 north through the cities of Ventura and Santa Barbara to Las Cruces and then northwest of Highways 1, 150, and Lompoc-Casmalia Road to the Pine Canyon Gate of VAFB. Highway 101 ranges from a four-lane undivided highway to an eight-lane divided highway over the entire length traversed. Highways 1, 150, and Lompoc-Casmalia Road are two-lane undivided highways. A small portion of Highway 1 winds through mountainous terrain.

One alternate route considered is described as follows: East on Devonshire Blvd to State Highway 7, then north on Highway 7 to US Highway 99, continuing north on Highway 99 to the intersection with State Highway 166, west on 166 to US Highway 101, south on 101 to Highway 1 and then continuing south on Highway 1 to VAFB. This route is not a direct route to VAFB and its length is considerably greater than that of the aforementioned route. In addition, Route 166 is a narrow, winding road where it crosses the Sierra Madre range.

Another route considered consists of traveling northwest on Highway 101 to the intersection with State Highway 399, north on 399 to 166 and then west on 166 to 1 as described in the preceding paragraph. Highway 399, however, crosses the San Raphael Mountains and is extremely narrow and winding through these mountains.

The final alternate route considered is described as follows: Highway 101 to Highway 399, north on 399 to its intersection with Highway 150 and then west on 150 to Lompoc. This route is, however, very narrow and is characterized throughout its length by many sharp curves. Figure 4-11 shows the locations of the four alternate routes.

4.1.2.6.2 Selected Route

The route to be followed in transporting the power system from Santa Susana to VAFB is described more fully below. Several sections of the route are described in detail. Since accidental water moderation and reflection can be a potentially serious problem with this type of reactor, the location of large collections of water along the route is indicated. It should be pointed out, however, that the shipping sleeve will maintain the reactor subcritical even if the core is completely submerged and flooded with water.

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Figure 4-11. Potential Power System Shipping Routes; Atomics International to Vandenberg Air Force Base

Figure 4-12 depicts the route. In the following discussion, the numbers noted are some tabulated probability values of truck accidents experienced in the past along particular sections of the route. These numbers were derived from accident data compiled by the California Division of Highways and involve 437 truck accidents during the years 1958 through 1960. All probability values for truck accidents given henceforth are based upon these data. These data were available only for accidents occurring outside the city limits of any community.

Santa Susana to Highway 101

The road in the area adjacent to Bldg 019 at the Santa Susana Field Test Laboratory is of narrow two-lane construction. There are numerous curves and fairly steep grades on the site, but traffic control is complete and the possibility of multiple vehicle accidents can therefore be eliminated. There are no significant collections of water adjacent to the road. The road becomes very steep and winding after passing the last guard post at Santa Susana. Sharp drops on one side of the road or the other are common, but the road is in good repair and traffic can be controlled to any desired extent. Large truck and trailers frequently use this road as access to the Field Test Laboratories. Three miles from the guard gate, the road from the Field Test Laboratory joins Valley Circle Blvd. This road is a fairly level two-lane pavement, but there are several sharp turns and curves before it joins Topanga Canyon Blvd. For a distance of about one-half mile, the Chatsworth reservoir is within sight of Valley Circle Blvd, but is at least 300 yd from the road.

Topanga Canyon Blvd is a two-lane road for about the first mile of the 5 miles traveled to Highway 101, the remainder being four-lane, divided. Each cross street is controlled by a traffic signal or stop sign. A portion of this route traverses residential area.

Highway 101 through Ventura

Highway 101 is an eight-lane divided freeway for about 1 mile after which it narrows to four-lane divided freeway. The route passes through the Santa Monica mountains west of Los Angeles.

A long downgrade, about 1 mile long, occurs just before Malibu Canyon Rd. After this point, the road is gently rolling, four-lane divided pavement. The probability of a truck accident in this section of highway has been 1.8×10^{-7} accidents per truck mile.

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Figure 4-12. Selected Power System Shipping Routes; Atomics International to Vandenberg Air Force Base

The highway starts to increase in slope and elevation near the city of Camarillo after which there is a long steep downgrade. There is a sheer drop of several hundred ft on the right side of the road in the middle portion of the downgrade. The rest of the road to the city of Ventura is flat and a grove of trees separates the opposing traffic for part of the way. The probability in this section of highway has been 5.5×10^{-7} truck accidents per truck mile. The road continues through Ventura as a divided freeway.

Ventura to Santa Barbara

After leaving Ventura, the first potential source of environmental water seen from the road is an intermittantly dry river bed 0.4 miles past the intersection of Highway 101 with Highway 88. The road is wide four-lane undivided highway where it crosses the bridge over the river bed. The amount of water present is uncertain at any given time, but the proximity of the ocean suggests that some tidal water may flow this far upstream during high tide. The depth of the stagnant water just after low tide on June 29, 1962 was about 1 ft.

The Pacific Ocean is seen from the road 0.7 miles past the river bed. Two hundred ft from the left side of the road for westbound traffic there is a steep 30 ft slope from the road to the water's edge. The road is a wide three-lane, or narrow four-lane, undivided highway in this area. The roadbed of the Southern Pacific railroad lies between the road and the water's edge for about 1 mile.

About 2.7 miles beyond the riverbed, the road lies about 100 ft from the water. The railroad moves away from the coast leaving only the sloping beach between the road and the water. The probability along this section of the route has been evaluated as 4.2×10^{-7} truck accidents per truck mile.

Figure 4-13 shows the highway, with the ocean in the background, about 6.7 miles beyond the riverbed. The water is about 10 ft from the left shoulder of the road. Figure 4-14 depicts the area 3 miles west of the point shown in Figure 4-13 and this is the spot where the highway becomes divided. Up to this point, it is a four-lane undivided highway. The accident probability in this section of the route has been 3.5×10^{-7} truck accidents per truck mile. The water reaches the rocks at high tide. The road remains adjacent to the water's edge for 3 miles past this point after which it turns inland. Rolling hills lie between the road and the coast for the remainder of the distance to Santa Barbara.

Figure 4-13. Highway 101 (7 miles NW of Ventura)

Figure 4-14. Highway 101 (10 miles NW of Ventura)

Santa Barbara to Intersection with Highway 1

The freeway passes under several bridges inside the city limits of Santa Barbara, but all of these have a minimum of 14-ft road clearance. The road is an eight-lane divided freeway inside the city and later changes to a four-lane divided freeway. It remains a four-lane divided freeway for about 17 miles at which point it changes to a four-lane undivided limited access road. Up to this point, the ocean is not visible from the road. At the point where the road changes from divided freeway to undivided road, the water is about 300 ft from the left shoulder of the road. There is a slight slope to the water's edge.

The grade of the road increases from this point until 1 mile further where there is a long steep slope to the beach. The road is about 100 ft above the water and about 300 ft away from it. The ocean does not come nearer than this to the road and can be seen only parts of the time for the next 9 miles. At this point, the road turns inland, north, away from the water and crosses over two high bridges. The ocean is visible at this point but is at least 300 ft away from the road. One mile further there is a tunnel through a hill. The road is four-lane divided highway at this point. The highway remains four-lane divided through the tunnel. Highway 1 turns off from 101 about 1-1/2 miles beyond the tunnel. The probability in this section has been 2.7×10^{-7} truck accidents per truck mile.

Highway 1 from Intersection with Highway 101 to Lompoc Area

Highway 1 is a two-lane road after it separates from Highway 101 and it immediately begins to climb through the mountains. As far as the town of Lompoc (about 20 miles), there are no significant environmental water sources adjacent to the road. Initially, where the road crosses the mountains, it is somewhat steep, narrow, and winding. However, Highway 1 is the route normally used by most of the truck traffic from the south to and through Lompoc. The probability of truck accidents along this road has been 8.9×10^{-7} per truck mile.

Lompoc Area to Vandenberg Air Force Base

About 1 mile from the city of Lompoc, Highway 1 intersects with Highway 150. A right turn is made onto Highway 150 at this point. Highway 150, a two-lane, asphalt paved road, is then followed in a northern direction for approximately 3 miles. At this point the route leaves Highway 150 and crosses to the Lompoc-Casmalia Rd by means of a stretch of asphalt connecting roadway approximately 300 yd long. About 1 mile from its intersection with

Highway 1, Highway 150 crosses a bridge over the Santa Ynez River. The river bed is usually dry, except during the rainy season (November through March or April). A left turn is made onto the Lompoc-Casmalia Rd and this route is followed for about 6 miles through gently rolling rural terrain. At this point, a two-lane road branches off to the west and proceeds 3/4 miles to the Pine Canyon Gate of Vandenberg Air Force Base (Figure 4-15).

Vandenberg Air Force Base, Pine Canyon Gate to SPTF

After passing through Pine Canyon Gate, the route continues along this road (now called Washington St) for about 2 miles until reaching the intersection with New Mexico Ave (Figure 4-16). The route turns left onto New Mexico Ave, proceeds for 1 mile to 13 St, turns left onto 13th St, proceeds for 1 mile to the SPTF access rd and turns right into the SPTF (SPTF can be seen at far right in Figure 4-16). Facilities for missile checkouts and base operations are located along New Mexico Ave and 13th St. No residential areas are passed. Figure 4-17 shows the location of the SPTF at VAFB.

4.1.2.6.3 Population Distribution Along Selected Route

The majority of the population along the route is concentrated in four areas. These are the community of Canoga Park, a suburb of Los Angeles, in Los Angeles County; and the cities of Ventura, in Ventura County, and Santa Barbara and Lompoc, in Santa Barbara County. The population of Canoga Park as of July 1, 1962 was 66,705 according to the Los Angeles County Planning Division. The Los Angeles Times Marketing Research Group lists the population of Ventura as 29,700 as of January 1, 1962. The same source lists the Santa Barbara and Lompoc populations as 61,200 and 18,900 respectively.

4.1.3 Accident Safeguards

The accident protection provided during transport of the power system incorporates a variety of design and procedural safeguards. These safeguards are discussed below.

4.1.3.1 Design Safeguards

The shipping sleeve, shipping container, and monitoring equipment are the primary design safeguards. The prime function of the shipping sleeve and container is to protect the reactor from hazardous environmental influences during transport, with the monitoring equipment providing continuous cognizance of the environmental status of the power system.

Figure 4-15. Pine Canyon Gate - VAFB

USAF Photo 3003

Figure 4-16. Intersection of New Mexico and 13th Streets - VAFB

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Figure 4-17. Location of SNAP Prelaunch Test Facility (Bldg 060) - VAFB

4.1.3.1.1 Shipping Sleeve

The shipping sleeve is designed to positively ensure the maintenance of the SNAP 10A reactor subcritical during shipment of the power system from Santa Susana to Bldg 060, VAFB. Since the greatest potential criticality hazard is posed by the accidental submergence of the reactor in a hydrogenous fluid, such as water, the sleeve is designed to provide sufficient reactivity protection even in the unlikely event that the reactor is totally externally reflected and internally flooded with such materials.

The SNAP Critical Assembly (SCA-4B) experiment^{5,6} has verified the adequacy of the shipping sleeve design in preventing criticality of the SNAP 10A flight reactor upon total water flooding and submersion. A sleeve has been designed that will maintain the bare flight reactor at least $\$1$ subcritical (Table 4-2, Appendix A) with total water flooding and submersion. Final experimental verification will be made with the actual sleeve and flight system reactor prior to shipment.

The sleeve is designed to withstand a 15-ft fall onto a solid rock or concrete surface without significant distortion or without breaking loose from the reactor.

The annular structure of the sleeve consists of a 3.75 in. layer of void cells, surrounded by a 1-in. layer of natural boron powder, which is followed by 1/4 in. of energy-absorbing material and 1/4 in. of 304 stainless steel. Figure 4-18 shows the design of the sleeve. The void cell section is divided into 144 watertight compartments by 0.01 in. sheets of 304 stainless steel. The steel occupies about 2.75% of the volume. Each compartment is so isolated from the others that, if one cell is punctured by a sharp object and becomes flooded with water, the rest of the compartment will remain empty.

The boron powder occupies the volume between the outside of the void cells and the 1/4 in. plate of energy-absorbing material. The powder is packed to approximately 20% theoretical density.

The energy-absorbing material consists of several 1/4-in. stainless steel spacers equally spaced around the steel container holding the boron powder. The spacers allow the external steel plate to deform plastically and absorb energy themselves by crushing.

The 1/4-in. stainless steel plate offers protection from puncture of the boron and void cell layers. The plate extends over both ends of the sleeve

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Figure 4-18. Power System Shipping Sleeve

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and anchors to the core vessel gridplates to supply structural integrity in that area. Impact loads which originate on the cylindrical portion of the sleeve are transmitted to the endplates and, from there, directly to the reactor core vessel. The thin gauge stock in the void region and the boron poison region are not load bearing members. The boron powder extends over the ends of the sleeve as a 1/4-in. layer.

The sleeve consists of two halves, each of which replaces one-half of the Be reflector. The halves are joined together with a total of 10 nutted bolts — five on each side. Two of these bolts — one on each side — function as interlocks and a special tool is required for their removal. Support hooks on the bottom and the top of the sleeve secure the sleeve to the reactor so that it will not slide up and down. Since the reactor core vessel has a tolerance in outer diameter of ± 0.03 in., the sleeve is designed so that its inner diameter is slightly oversize to compensate for variations in the core vessels.

4.1.3.1.2 Power System Shipping Container

The shipping container consists of an inner and an outer container and is designed to hold the power system in its handling fixture during shipment from Santa Susana to Bldg 060 at VAFB and from Bldg 060 to the launch pad. (Figure 4-19). An argon atmosphere of 2.7 psig is maintained in the container when the APU is inside. The container is double-walled and the inner portion is shock-mounted so that the loads to the inner container are less than 2 g for loads up to 5 g to the outer container.

The inner container consists of a top section and a bottom section and is a sealed container capable of maintaining a pressure of 2.7 ± 0.3 psig. The design facilitates the positioning and fastening of the top section to the bottom section with the use of swing bolt latches to provide a snug, leakproof container. An automatic regulator provides for purging and pressurizing with argon gas.

The inner container includes a relief valve set at 5 ± 0.5 psig and a manual relief valve and also contains a bulkhead type electric connector. The gas inlet and the electrical connector are in the bottom section and the manual relief valve is in the top section of the container. The maximum leakage rate of the inner container is 1/10 psig/30 min with 3 psig inside the container. The container is designed for a proof pressure of 7 psig.

Figure 4-19. Power System Shipping Container

The outer container is a free-breathing lightweight shell consisting of a top section and a bottom section. The design facilitates the positioning and fastening of the top section to the bottom section with swing bolt latches. Provisions are incorporated to insure free drainage of all water entrapments when the container is in normal storage position. The inner container is suspended inside the outer container within a shock and vibration isolation system capable of limiting loads to the inner container to 10 g when the container is subjected to rough handling tests (specified below in the description of quality assurance provisions). Also, the capability exists to limit loads on the inner container to 2 g or less when shockloads of 5 g for 10 msec duration are applied to the outer container. The pneumatic and electrical lines from the inner container are accessible at the exterior of the outer container. Provisions are made for mounting and replacing two standard 330 ft³ argon cylinders with valving and connections to the pneumatic purge line. Valving is arranged so that either cylinder may be used separately.

Prior to acceptance, the shipping container shall pass certain qualification tests. Several of the more significant tests are outlined below:

Leak Test

The empty container shall be assembled closed in the same manner as it is prepared for shipment except that there is no requirement that the top section of the outer shell be in place. The system shall be pressurized through the external purging and pressurizing port to 3 ± 0.03 psig. The pressurizing source shall be shut off simultaneously with the beginning of the leakage check. After 30 min elapsed time, the leakage shall not have exceeded 1/10 psig.

If the container satisfactorily passes the leak test requirements, the relief valve shall be removed. The outlet port shall be sealed and a proof pressure of 7 psig shall be applied and maintained at that level for 5 min. The container shall not exhibit permanent distortion or deformation after this test.

Rough Handling Tests

The acceptance criterion of the rough handling tests is that the damage resulting from these tests will not interfere with the function or use of the container. Rough handling tests are:

- a) Test Load - The container, closed as for shipment, will be subjected to rough handling tests with a dummy load simulating the

actual equipment as to weight, envelope dimensions and center of gravity.

- not as stringent as drop tests in proposed 10 CFR 71*
- b) Rotational Drop Test - The container shall be supported at one end at the extreme bottom edge on a block 5 in. high. The other end shall be raised to a height of 12 in. and allowed to fall freely on a concrete or steel surface. This test shall be performed once to each end of the container.
 - c) Flat Bottom Drop Tests - The container shall be raised to a height of 12 in. and allowed to fall freely to a hard, level concrete floor or equal surface.
 - d) Impact Tests - The container shall be impacted on each end and both sides. Each applicable surface shall be impacted by dropping from a height of 9 in.

Following the rough handling test, the leak test will be repeated.

4.1.3.1.3 Power System Shipment Monitoring Equipment

The basic monitoring equipment was described previously in 4.1.2.2.2. The monitoring instrumentation for radiation detection, argon gas pressure, shock-vibration measurement, and NaK leakage are as follows:

Gamma Radiation Detection

A gamma-measuring instrument output will be recorded. Any indication of gamma radiation above the residual radiation level will be checked with portable monitoring equipment.

Pressure Measurement

The argon pressure inside the power system shipping container will be recorded. It is required that a positive internal pressure be maintained with respect to the atmosphere. Deviations from the prescribed pressure condition will not call for emergency measures but will be evaluated for possible adverse effects. If action is required, the test program will include remedial action. During shipment, deviations that exceed prescribed limits will be indicated by lights on the monitoring panel.

Shock and Vibration Measurement

Three orthogonally mounted accelerometers will measure the shock and vibration during shipment. Panel lights will indicate shocks in excess of 2 g

along the transverse and vertical axes and will indicate shocks in excess of 7 g along the longitudinal axis of the power system. If excessive shocks and vibrations have been experienced, extra care will be taken during unpackaging of the power system.

NaK Leakage Detection

A sensing device capable of detecting the presence of NaK within the power system shipping container will be in operation. This device consists of several mylar sheets on which juxtaposed thin copper strips are electrodeposited. An electrical potential is applied across these strips, resulting in a flow of current whenever a drop of NaK shorts one of the strips to the adjacent strip. The current is indicated on the display panel and also activates a panel alarm light and registers an event on the oscillograph.

4.1.3.2 Procedural Safeguards

4.1.3.2.1 Route Selection

The route chosen is the most practical, both from operational and safety viewpoints, of several possible choices (a discussion of each is found in 4.1.2.6.1). The route is a wide divided highway over a large portion of the trip and thus the chance of a head-on collision with another vehicle is much less than it would be were a narrower highway chosen as the route. The section of the highway that lies near the coast traverses flat land or gently rolling hills and the possibility of a runaway vehicle due to brake or tire failure is decreased. The route bypasses most populated areas. Canoga Park and Santa Barbara are the only cities in which dense vehicular traffic could be encountered, although the time of shipment will minimize this possibility.

4.1.3.2.2 Method of Transport

Truck transportation was chosen because it offers the best overall advantages of three possible modes of transportation: truck, railroad, or air. Although the truck must travel on highways frequented by a large number of passenger cars, the departure time will be chosen to coincide with minimal auto traffic and optimal weather conditions. The convoy system will provide the transporting truck with a large measure of protection from the possibility of unanticipated events.

4.1.3.2.3 Procedures

A manual covering the detailed procedures for handling and shipment will be written and available prior to the time of shipment.⁷ Included in this manual will be emergency plans to be followed should a transportation accident occur. Responsibilities, as well as those persons to be informed in case of an accident, will be specified. Instructions will be given for the cleanup of any debris in the area. Personnel will be thoroughly trained to recognize and properly handle hazardous situations which credibly might arise during shipment. For information purposes, some of the basic emergency plan action is presented below:

- a) The technician monitoring the display panel in the cab of the transport vehicle will direct the driver to stop whenever the panel indicates a significant change in the power system environment.
- b) In the event a pressure drop is indicated, the transport vehicle will be stopped and additional argon will be added to the shipping container to reestablish the desired pressure.
- c) In the event high radiation levels are indicated, the transport vehicle will stop and the radiation levels will be checked with portable survey instruments. No nuclear incident is credible during normal shipment operations and indicated high levels will therefore be regarded as spurious if no increased radiation levels can be observed with portable survey instruments. Radiation levels for the remainder of the trip will be documented with portable survey instruments located in the transport vehicle cab.
- d) In the event the monitoring system indicates the presence of a NaK leak or of excessive temperatures in the shipping container, the transport vehicle will be stopped and an examination of the monitoring system will be made in an attempt to establish whether the indication is spurious. If it cannot be positively established that the indication is spurious the caravan will turn around and return to Santa Susana.
- e) In the event of a flat tire or other mechanical breakdown of minor magnitude the transport vehicle will be removed, as much as possible, from the highway and repairs will be facilitated. During the period of repair operations, the escort vehicles will be parked

in front and in back of the transport vehicle. The personnel of the escort vehicles will:

- 1) Place warning lights or flares in the roadway as specified by ICC regulations.
- 2) Render whatever aid is necessary to facilitate the repair operations and to insure the security of the unit.

The technician who is monitoring the console in the truck will remain at his station during repair operations. After repairs are completed the delay will be noted in the trip log and the caravan will continue. No notification procedures are required for delays of less than two hours.

- f) In the event of a mechanical breakdown of major magnitude, or an accident which damages the transport vehicle to the degree that ~~it~~ cannot reasonably continue, but which does no apparent damage to the unit or its container, the personnel in the escort vehicles will:

- 1) Place warning lights or flares as specified by ICC regulations.
- 2) Restrict access to the transport vehicle and the APU container.
- 3) Determine as much as possible by console and other instrument readings that the unit is undamaged and safe.
- 4) Notify AI Industrial Security and AI Health and Safety by telephone.
- 5) Guide responding firemen as to limitations on fire fighting if a fire develops.
- 6) Supervise any movement of wreckage to assure no damage to the unit or the shipping container occurs.
- 7) Remain at the scene until another transport vehicle arrives.

- g) In the event the accident appears to have damaged the unit or its container the escorting personnel will, in addition to above procedures:

- subsequent incident not possible*
- 1) Determine that no radiation hazards exist.
 - 2) Acquire police aid in isolating the area and detouring traffic.
 - 3) ~~Prevent any possibility of a nuclear incident by preventing water immersion or the disturbance of the APU or shipping container.~~

4.1.4 Potential Shipment Accidents and Effect on Power System

Potential accidents that could occur during shipment of the power system are described and discussed in the following section together with the safeguards which will minimize the probability of occurrence of such accidents. The potential effects of these accidents on the power system are also evaluated.

4.1.4.1 Discussion of Potential Shipment Accidents

The most credible types of shipment accidents are those in which the transport truck collides with a second vehicle and those which result from a transporting vehicle failure.

4.1.4.1.1 Collision with a Second Vehicle

During transport, many vehicles will be encountered and each of these vehicles would pose a hazard should either vehicle leave its lane of travel and approach or enter the lane of the other vehicle. Data for the years 1958 through 1960, covering a total of 2217 vehicle accidents along the selected route, were obtained from the California Division of Highways. Of these accidents, 437 involved a truck. Section 4.1.2.6.2 lists some of the probabilities, obtained from these data, of a two-vehicle truck accident occurrence for various sections of the route. These probabilities include all accidents that occurred during all times of the day. Figure 4-20 illustrates the relationship of the number of accidents to the time of the day. It is seen that the period from the late evening through the early morning hours is the period of fewest accidents. The lower accident probability during this period is apparently due to the presence of fewer vehicles on the highways during these hours. The selection of the time of travel to coincide with the lowest vehicular traffic density will appreciably reduce the probability of a collision with a second vehicle.

The most severe credible collision would probably be that involving two trucks. Of the 437 truck accidents listed, only 26, or about 6%, were of the two-truck category. Thus, the probability of this type of accident is reduced by greater than an order of magnitude from the probability of an accident involving a truck and an automobile.

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Figure 4-20. Number of Truck Accidents vs Time of Day Along Portions of Shipment Route

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A two-truck accident in which the second truck is a gasoline tanker appears to be the most severe accident possible, as the large quantity of fuel available would increase the possibility and the magnitude of a fire. During the three years surveyed by the data, only two accidents involved a tanker. The other vehicle in each of these accidents was a passenger car. Therefore, the probability of an accident involving the power system transport vehicle and a gasoline tanker during the trip appears extremely small ($<10^{-7}$).

4.1.4.1.2 Single Vehicle Accidents

Tire failure could cause a severe accident should the failure occur while a vehicle is traveling at a high rate of speed. Complete loss of control may occur if one of the front tires fails, though the danger is not so great if the failing tire is one of the rear tires.

Although the possibility of tire failure exists, the hazard to the transport truck and its cargo from such failure would not be great since the truck will be traveling at a rate of speed no greater than 30 to 35 mph and this speed is low enough to allow the driver to remain in control of the truck. To further reduce the danger of tire failure, the tires will be thoroughly inspected prior to shipment.

Truck brakes undergo a severe strain during stops and during deceleration on a downgrade. In the event of truck brake failure during transit, the truck could conceivably go out of control and overturn. This possibility is, however, reduced since the transport vehicle will be equipped with a safety device which automatically locks the brakes whenever the air pressure in the air brake system falls below a safe level. The most likely cause of brake failure would be brake overheating during a long downhill grade. Such overheating could cause brake "fading." The possibility of fading will be reduced by the low rate of speed at which the transport truck will travel, thereby making excessive braking unnecessary. The brakes will be thoroughly inspected prior to power system shipment.

4.1.4.1.3 Driver Error

Apart from potential vehicle failures, there remains, of course, the possibility of driver error or collapse. This type of failure could conceivably result in a most severe accident. Only experienced drivers will be utilized and the presence of the technician in the truck cab during shipment will preclude any need for the driver to divide his attention between the road and the monitoring equipment.

In summary, vehicle accidents during shipment, although unlikely, are always possible, regardless of the amount of precaution taken and the safeguards provided. They may range in severity from simple breakdowns to violent collision, with a corresponding decrease in probability. The potential effects of such accidents on the power system and possible hazardous conditions which could result are discussed in the next section.

4.1.4.2 Potential Consequences of Transportation Accidents on the Power System

The consequences of a collision with a second vehicle, or of an accident involving a mechanical failure of the truck, will obviously depend to a large extent upon the severity of the accident. Only those accidents which would involve sufficient force to rupture the integrity of the inner container are considered as significant problems.

Should a fire occur and not reach the power system, the LiH radiation shield, or the Be reflector, the only danger would be from the spread of the fire to structures, other vehicles, or nearby vegetation. This hazard can be met by standard fire fighting techniques.

Accidents which would result in the rupture of the power system shipping container would present a possible toxicity problem only if the NaK plumbing were broken. The possibility of a NaK fire and the effects on other materials that are shipped with the APU are discussed below.

4.1.4.2.1 NaK Fire

While considerable information exists on the temperatures attained and the mechanics of sodium fires⁸, very little specific data are available for NaK (78%K, 22%Na fires). Generally, it is assumed here that the characteristics of a NaK fire would be similar to that of one involving sodium alone. The principal reaction products would be sodium and potassium oxides. The reaction would be characterized by very low flames and dense clouds of white smoke. Experiments have shown that, when a spray of sodium is burned in air, transient temperatures up to about 1620°F (the boiling point) may be attained. However, the equilibrium temperature of relatively small pools of burning sodium is lower, about 1200°F.⁸ This latter temperature is probably a conservative maximum to use for NaK fires also; but because of the lack of specific information, a maximum fire temperature of 1436°F, the boiling point of NaK, was assumed in the succeeding analysis. In

most instances only a fraction of the liquid metal is carried away in the form of smoke. Most of it remains as residue in the form of oxides or unreacted metal.⁸

In the event that a fire does start, past experience has shown that the security police and groundhandling crew accompanying the shipment should be able to extinguish the fire within a short period of time if only NaK is involved. There are several materials which have been used to extinguish sodium and NaK fires. The most effective one, to date, is Met-L-X (sodium chloride). Probably because sodium chloride fuses at temperatures slightly above 1200°F and forms a crust which floats on the surface of the NaK, Met-L-X becomes more effective as the temperature of the NaK fire increases. The escort vehicles will be equipped with extinguishers of this type.

The toxic hazard resulting from fires involving NaK is the formation of airborne sodium and potassium oxides.

The maximum amount of sodium and potassium oxides that may become airborne will be relatively small (~52 lb) since the total amount of NaK in the power system amounts to only about 29 lb. Figure 4-21 shows that 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.

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Figure 4-21. NaK Fire Burning Time as Function
of Puddle Size

4.1.4.2.2 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 ug/m^3) airborne maximum acceptable concentration (MAC)⁹ because it absorbs water from the lung tissue to form LiOH. 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 (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).⁽⁹⁾

Experiments to determine the ignition temperature, rate of moisture pickup, and outgassing of solid cold-pressed lithium hydride in different environments have been completed.¹⁰ 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 airflow tends to decrease the ignition temperature. Once ignited, temperatures as low as 500°F have been observed to support combustion.

The upper limit on the amount of LiH which could be ignited in a 30-min NaK fire, using 500°F as the ignition point, is also of interest. At a NaK fire temperature of 1436°F , assuming the temperature gradient across the LiH is small, the time for the LiH to reach 500°F through convection was determined as a function of mass and convection area of the LiH segment as follows:

$$MC_p (T) \frac{dT}{dt} = Ah (1436^\circ - T)$$

where

- C_p = specific heat (assumed constant = $1.1 \frac{\text{Btu}}{\text{lb-}^\circ\text{F}}$),
 M = mass of LiH,
 T = temperature of LiH,
 A = convection area,
 h = heat transfer coefficient ($\sim 10 \frac{\text{Btu}}{\text{hr-}^\circ\text{F-ft}^2}$), and
 t = time in hours.

The solution of this equation yields,

$$t \text{ (minutes)} = 2.8 \frac{M(\text{lb})}{A(\text{ft}^2)}$$

Assuming a cylindrical shape and letting $A = \pi Rl$, $t \text{ (minutes)} = 2.8 \rho R$ where $\rho = \text{LiH density (46.5 lb/ft}^3\text{)}$, and $R = t/130 \text{ ft}$.

Since for a 30-min fire, R equals 0.23 ft, the mass of the LiH cylinder for the 2.9 ft diameter NaK puddle is 22.6 lb.

$$\text{Mass} = \pi (0.23)^2 \times 2.9 \times 46.5 = 22.6$$

Comparison of the rate of change of temperature with time for convection and radiation is shown below for two temperatures: 70°F and 500°F. A conservative emissivity value of one was used for the radiation calculation.

RATE OF TEMPERATURE INCREASE

(°F/hr)

Temperature	Radiation	Convection
70°F	$2.06 \times 10^4 \frac{A}{M}$	$1.23 \times 10^4 \frac{A}{M}$
500°F	$1.93 \times 10^4 \frac{A}{M}$	$8.52 \times 10^3 \frac{A}{M}$

Due to the similarity in rate of heat transfer by the two methods, the previously calculated 22.6 lb weight of LiH was doubled. Therefore, in a 30-min NaK fire, assuming that the LiH shield was released from its shipping container, fractured and fully exposed to the fire, fragments up to a maximum of about 45 lb could ignite at about the time the NaK fire is consummated. However, in an accident which involves a gasoline tanker and resultant fire, temperatures of the order of 2000°F could be sustained for 30 min to 1 hr. In this case, the entire shield might be consumed.

4.1.4.2.3 Beryllium Involvement

The beryllium portion of the shipment will be packaged and transported within the requirements as specified in Atomic International Standard Operating

Policies¹¹ and ICC regulations, and further evaluation of it is not considered appropriate to the safeguards analysis. However, the following general comments are made:

- a) The temperatures to which the Be might be exposed in the postulated NaK fire discussed in 4.1.4.2.1 could not possibly result in a significant airborne release of Be or BeO.³
- b) Involvement of the Be in a large gasoline fire (i.e., 2000°F for 30 min) could result in the surface formation of 1 or 2 lb of BeO,¹ but a negligible fraction of this amount would become available for airborne dispersal as respiratory-sized particles.¹²

4.1.2.2.4 Uranium Involvement

Although the gas-tight integrity of the fuel element cladding is disrupted at a temperature of about 1600°F, recent experiments during some fission product release tests¹³ indicate that no gross failure occurs prior to about 2400°F, at which temperature melting of the cladding was observed. Any significant release of uranium as an aerosol is, therefore, very unlikely because the fuel elements must reach 2400°F before any appreciable uranium exposure occurs. Since the temperature of a NaK fire cannot exceed about 1436°F, no release of uranium appears possible in this case. The fire temperature during a gasoline fire may reach 2000°F, but gross fuel element cladding failure (i.e., exposing a large surface of fuel) still should not occur. It is conceivable, however, that, in an extremely violent accident, some of the fuel elements might suffer cladding damage, thereby offering potential fuel oxidation surfaces, should a fire result.

4.1.4.2.5 Fission Product Inventory Involvement

The same general considerations apply to the fission product inventory as discussed for the uranium. However, due to the greater volatility of certain fission product elements (e.g., Kr, Xe, I, Br, Cs, etc), the percentage released could exceed that of the uranium. In any case, the amounts would be small since, at the time of shipment, only about 10 mc total fission products are present in the core, of which approximately 2 mc is composed of the volatile elements (I¹³¹ and Xe¹³³).

4.1.4.2.6 Nuclear Accidents

It is adjudged that the overall safeguards provided for the shipment remove, beyond the bounds of credibility, the possibility of an accident which

results in criticality of the reactor. This conclusion is based on the consideration of the sequence of events which would be necessary for criticality to occur. This sequence is summarized below:

- a) A truck accident must occur.
- b) The accident must be severe enough to breach the watertight integrity of the inner shipping container.
- c) The breached container must be so located that flooding with water or hydrogenous fluid may occur, (or the power system must be released from the shipping container into water).
- d) The nuclear protection of the shipping sleeve must be forcibly eliminated without significantly distorting the core geometry.

*Core geometry
distorted can
cause criticality*

The probability for (a) above has been about 1×10^{-7} per truck mile along this route in the past, or a total trip accident probability of about 1.5×10^{-5} . Certainly, the escort provided, selection of optimum weather and traffic conditions, and the reduced speed enforced, significantly reduce this probability. Even in the event of a truck accident, (b) and (c) are highly unlikely. The ocean, which represents the only appreciable water source along the route, is in proximity of the highway for a total of about 30 miles, or approximately 20% of the trip. Other potential fluid sources (e.g., tanker trucks, etc) appear even less credible. In any case, even assuming the occurrence of events (a), (b), and (c), the shipping sleeve provides a final safeguard against criticality.

4.1.5 Maximum Credible Accident

4.1.5.1 Description

The maximum credible accident is conservatively assumed to occur as a result of a head-on collision between the transporting truck and a second vehicle. To further maximize the accident, it is postulated that the second vehicle is carrying a large quantity of inflammable liquid and that a major fire ensues. It is further assumed that the power system and shield shipping containers are breached by the force of the collision and both the reactor and shield are fully exposed to the fire. An evaluation of the potential hazards from such an event follows below.

4.1.5.2 Evaluation of Potential Consequences of Maximum Credible Accident

4.1.5.2.1 NaK

NaK involvement in the postulated accident and fire will occur if the power system piping is ruptured. The amount of NaK that escapes and burns is conservatively taken as the total inventory, 28.9 lb. The principal hazard resulting from this source is the formation of sodium and potassium oxides which may become airborne. These alkali compounds have an airborne MAC of 2 mg/m^3 over an 8-hr period.⁹ Since these materials are chemical irritants only, a concentration of 20 mg/m^3 (ten times MAC for 8-hr period) for short exposure periods (less than 1 hr) is probably a reasonable value. The resultant airborne concentrations of the NaK oxides directly downwind is shown in Figure 4-22. These calculations were made using the Sutton diffusion model¹⁴ assuming meteorological parameters typical of very poor atmospheric dispersal conditions (strong inversion). A continuous, uniform release was assumed over a 30-min period. Concentration values are shown for two different initial cloud rise heights, 50 and 100 ft. Any initial rise of less than 50 ft is not considered realistic in view of the large amount of heat released in the fire. It can be seen from this figure that the maximum concentration occurs about 6,500 ft downwind and has a value of 2.6 mg/m^3 at this point for the 50-ft cloud rise case.

4.1.5.2.2 LiH

It is assumed that the shield casing has failed in the accident thereby exposing the LiH to the fire. The burning rate of LiH is not known but, for computational purposes, complete consumption of the material during 30 min is postulated. Longer or shorter burning times would change the downwind concentrations proportionately. The downwind concentrations are also shown in Figure 4-22 in a manner similar to that for the NaK. The continuous MAC is temporarily exceeded in this case for both the assumed 50 and 100-ft initial cloud rise. Also, the short term MAC for the 50-ft release is temporarily approached. However, the conservatism of the assumptions is so severe, (100% LiH release, no fall-out, constant wind direction, ect) that the values plotted are almost certainly overestimates. In any case, the potential hazard does not appear extreme.

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Figure 4-22. Alkali Oxide Concentrations as a Function of Downwind Distance from a 30-Min Fire

4.1.5.2.3 Uranium

The 37 fuel elements contain a total of 10.86 lb of uranium with an isotopic breakdown as shown in Table 4-1.

TABLE 4-1
ISOTOPIC URANIUM CONTENT OF SNAP 10A REACTOR FUEL

Isotope	wt %	gm	curies
U ²³⁴	1.09	54	3.3×10^{-1}
U ²³⁵	93.19	4,590	9.9×10^{-3}
U ²³⁶	0.45	22	1.4×10^{-3}
U ²³⁸	5.27	260	8.7×10^{-5}

Since the gamma radiation from these isotopes is negligible, the only potential source of a significant hazard is internal body contamination through the inhalation of airborne particles that might result from uranium involvement in the postulated fire. As discussed in 4.1.4.2.3, the reactor vessel and the fuel element cladding itself should effectively prevent significant exposure of the uranium. However, to examine the potential hazard posed by this material, a 1% airborne release was arbitrarily assumed to occur as a result of the maximum credible accident.

For short exposure periods, as would result from the 30-min fire, and assuming the airborne uranium would be in an insoluble form,^{*} the lung was selected as the critical organ.

The dose received by the lung in a 1-yr period following the exposure (~88% of the total dose) was calculated as follows, using the equation for short term exposure where the lung is the critical organ, derived by Morgan,¹⁵

$$D = \frac{Q_I T \Sigma (bE)(RBE)n \left[T_r \left(1 - e^{-0.693t_1/T_r} \right) - 0.693t_1 e^{-0.693t_2/T} \right]}{75t_1}$$

^{*}The dose received by the lung is greater than the doses received considering the GI tract (insol), or kidney (sol) as the critical organ.¹⁵

where,

D = dose to lung in 1 yr, rem

Q_I = quantity of material inhaled, μc

T_r = radioactive half-life of material

T_b = biological half-life of material (120 days for lung)

T = effective half-life $\left(\frac{T_r T_b}{T_r + T_b} \right)$

$\Sigma(bE)(RBE)n$ = effective energy term

RBE = Relative Biological Effectiveness ($\beta, \gamma = 1$; $\alpha = 10$)

bE = total energy absorbed in body organ per disintegration, Mev

n = Relative damage factor

t_2 = exposure time of critical organ (1 yr)

t_1 = inhalation time

For long radioactive half-lives and short inhalation times this equation, after substitution of the values for T and t_2 , reduces to,

$$D = 0.973 Q_I \Sigma(bE)(RBE)n$$

For the different uranium isotopes listed in Table 4-1, the relative dose contribution depends only on the quantity (c) and the value of the $\Sigma(bE)(RBE)n$ term. Since these latter values range from 43 (U^{238}) to 49 (U^{234}),⁽¹⁶⁾ it can be readily shown that the U^{234} contributes more than 97% of the total dose. Thus, in the dose calculations, only the U^{234} was considered. To obtain the amount of U^{234} inhaled (Q_I), the following relationship is used,

$$Q_I = TIE \times R$$

where,

$$TIE = \text{Total integrated exposure, } \frac{\mu c - \text{sec}}{cc} = \frac{2Q}{\pi C_y C_z \bar{u} X^{2-n}} e \left[-\frac{h^2}{C_y^2 X^{2-n}} \right]$$

$\bar{u}; n; C_y; C_z$ = Sutton diffusion parameters (Figure 4-23)

h = release height (meters)

R = breathing rate cc/sec (=347)

Q = amount of uranium becoming airborne, μc

The TIE values, as a function of downwind distance, were also derived from the Sutton diffusion model. Figure 4-23 illustrates the results of these calculations using meteorological assumptions as with the NaK and LiH. It can be seen from this figure that the maximum dose potential is about 13 mrem. The doses that would result from different release fractions can be scaled proportionately from this curve, but values higher than the assumed 1% are not considered credible.

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Figure 4-23. Potential Lung Dose from Uranium Inhalation vs Downwind Distance

4.1.5.2.4 Fission Products

Potential inhalation doses of the residual fission product inventory resulting from acceptance testing are negligible. For example, if the entire amount of I^{131} were released (~ 1 mc), the maximum thyroid dose downwind would be less

than 1 mrem. Since the total inventory is only about 10 mc, the airborne release of all the radioactivity would be an insignificant hazard source.

4.1.6 Summary and Conclusions

Although an extensive effort is made to prevent potentially damaging accidents during the shipment of the SNAP 10 power system from Santa Susana to VAFB, the possibility of vehicle accidents cannot be completely eliminated. The magnitude of such accidents can credibly range from simple transporting vehicle failures through major two-or-more vehicle collisions. Impact forces alone, although sufficient to cause serious damage to the power system, could not create unique hazards arising from the presence of the power system components (with the minor exception of a small NaK fire). An accident could conceivably result in a gasoline fire of considerable magnitude. Under proper conditions, the various components of the power system could be exposed to such a fire. The NaK coolant, LiH shield, uranium fuel and the small residual fission product inventory can present a potential hazard to the environs only by an airborne particle dispersion, which could result from the fire. A conservative evaluation of these hazards indicates their injury potential is quite small.

The only other conceivable hazard peculiar to the power system shipment is accidental criticality of the reactor. Because of the potential seriousness of such an event, a safeguard has been provided in addition to those which offer protection against the nonnuclear hazards. This safeguard, the shipping sleeve, reduces the already highly remote probability of a nuclear incident to a point beyond credibility by maintaining reactor subcriticality even under the worst environmental condition of complete water reflection and internal flooding of the core.

Therefore, in view of the small probability of an accident and the limited magnitude of the resultant hazards should an accident occur, the safeguards provided for the power system shipment appear to be more than adequate.

4.2 VANDENBERG AIR FORCE BASE TO NAVAL MISSILE FACILITY,
POINT ARGUELLO

4.2.1 Preshipment Operations

4.2.1.1 Ground Handling Equipment

The power system handling equipment used at Bldg 060, VAFB, is of the same type and design as that used at Bldg 019, Santa Susana. A description of this equipment is found in Section 4.1.1.2.

4.2.1.2 SPTF Operations

The operations performed subsequent to the power system's arrival at the SPTF (Bldg 060) are presented in detail in References 4 and 17. A brief summary is given below for purposes of continuity.

After arrival of the power system at the SPTF, an inspection will be made for damage during the shipment. The shipping container is removed by forklift from the transporting vehicle. The outer cover of the upper half of the shipping container and the attached monitoring equipment are removed. The inner part of the upper half of the shipping container is then removed and the tilt-sling is attached to the power system in its handling fixture. Entry into the bottom half of the container will be restricted until the argon is dissipated. The power system is then removed, in the horizontal position, from the bottom half of the shipping container, rotated to the vertical position and set down upon the vertical support stand.

An inspection is made of the entire power system to locate any visible damage. Continuity checks are made of the electrical converters and of all other electrical systems. Minor damage can be corrected at the SPTF. Major damage may necessitate return of the power system to Santa Susana for repair. In the event a return trip is required, it will be carried out with procedures similar to those described in this report.

The reflector assembly is checked for damage to see that each control drum correctly rotates into its inward position. The reflector assembly is separate from the power system at this time.

The LiH radiation shield is surveyed for damage and any minor damage corrected. Following this inspection, the radiation shield is mounted on the shield installation fixture, placed underneath the power system in its handling

fixture, and raised by the hydraulic ram into the bottom of the power system. It is then secured at the bottom of the reactor.

The reflector halves, with the void-filler blocks in place, are each mounted on the reflector handling fixture. The shipping sleeve is removed from the reactor one-half at a time and replaced by the appropriate reflector half. At no time are both halves of the shipping sleeve removed together, exposing a completely bare core. The second half of the shipping sleeve is removed and replaced by the second reflector half. Numerous nonnuclear tests will be performed on the power system before it is ready for shipment to NMFFPA.

4.2.1.3 Preparation for Shipment

About 2 wk before the scheduled launch date, the power system will be transported to Point Arguello Launch Complex, 2(PALC-2) at the NMFFPA. The power system, now with the reflector-void filler block combination replacing the shipping sleeve around the reactor, and with the LiH shield in place, will be returned to the same shipping container used during the SS-VAFB shipment. Following the replacement of the inner and outer halves of the shipping container, the inner container will again be purged with argon and pressurized with argon to 2.75 psig. The shipping container will be placed on the transporting vehicle and the monitoring instrumentation placed in operation. The power system is now ready for transportation to the launch pad.

4.2.2 Shipment Operations

4.2.2.1 Shipment Containers Description

The power system shipment container is identical to that described in 4.1.2.1.4. Since the reflector and LiH shield are now integrated with the power system, only the heat shield is shipped in a separate container (see 4.1.2.1.2).

4.2.2.2 Safety Equipment Description

The principal safety equipment used during shipment consists of (1) the reflector void-filler blocks and, (2) the power system shipping container monitoring equipment.

4.2.2.2.1 Void Filler Blocks

These devices are integrated with the reflector assembly to provide assurance that (1), inward motion of the control drums is positively prevented

and (2), the effect of external environmental influences cannot result in criticality of the reactor. Because of the importance of the void filler blocks to the overall safeguards provided during this phase of the shipment, a detailed description is presented under Design Safeguards (4.2.3.1).

4.2.2.2.2 Power System Shipping Container Monitoring Equipment

This equipment is identical to that described in 4.1.2.2.2

4.2.2.3 Transporting Vehicle Description

This vehicle is similar to that described in 4.1.2.3.

4.2.2.4 Shipment Personnel

Shipment personnel will be the same as discussed in 4.1.2.4, with the probable addition of a military escort.

4.2.2.5 Shipment Procedures

A detailed shipping procedure manual¹⁸ will be prepared and receive the necessary approvals prior to shipment. This manual will contain specific instructions to be followed during transport, including emergency action in the event of accidents enroute. In general, however, the following principles will be employed:

- a) The approximately 1-hr trip will be scheduled for hours of minimum traffic. Complete traffic control will be effected during the trip.
- b) The trip will not be scheduled with adverse weather existing or expected (i.e., rain, fog, high winds, etc).
- c) The maximum speed of the truck will be restricted to a safe value probably resulting in an average of about 10 mph for the trip.
- d) One escort vehicle will precede the truck and one will follow.

4.2.2.6 Route Description

The route chosen between the SPTF and PALC-2 offers the most direct route and the larger portion of it lies on government property. It is described as follows: North on 13th St for about 1 mile after leaving the 1000-ft SPTF driveway, left on New Mexico Ave (which later becomes 35th St) hence southwest for

about 4-1/2 miles to the VAFB Surf Gate. One-quarter of a mile beyond, the road crosses the bridge over the Santa Ynez River (~1/4 mile) and about 1/4-mile further the intersection with the Lompoc-Surf Rd (Highway 154) is reached. Right (west) on this road, through the settlement of Surf, for about 1 mile to the NMFPFA Surf Gate. Down the coast road (south) paralleling the ocean on Navy property for a distance of approximately 3-1/2 miles, then east for 1/2 mile to PALC-2. The entire route is shown in Figure 4-24. Figures 4-25 through 4-31 are photographs along the route as noted. Further descriptive details of the route are presented below.

SPTF to Surf Gate - VAFB

This portion of the route (~5 miles) is entirely within VAFB. As can be seen from Figure 4-25 and 4-26, the road is of two-lane, well-maintained construction. The first 2 miles along New Mexico Ave are adjacent to a number of small buildings and also portions of a house trailer establishment for military personnel and their dependents. The latter part of this section progresses along 35th St and down an unpopulated slope to the Surf Gate.

Santa Ynez River Bridge

About 1/4 mile beyond the VAFB Surf Gate, the bridge over the Santa Ynez River is encountered. The somewhat winding descent down the slope from VAFB ends prior to this bridge, and a fairly long, straight, and level approach exists (see Figure 4-27). This bridge crosses the Santa Ynez about 1 mile above its outlet into the ocean. At this point, ocean tidal ebb and flow influences the depth of water; however, depths exceeding 10 ft probably are often present. The surface of the water is about 15 ft below the roadway. A closer view of the bridge is shown in Figure 4-28. As can be noted from these two figures, the immediate area is unpopulated.

Lompoc - Surf Road (Highway 150) to NMFPFA-Surf Gate

The small railroad employees' town of Surf, Figure 4-29, has a somewhat transient population with an average of about 50 persons. There is an agreement with the railroad that the population may be temporarily evacuated for certain missile launches from VAFB if deemed advisable. (No such evacuation is deemed necessary for the power system shipment, however). The only other town of appreciable size in the vicinity is Lompoc (population 18,900) which is a minimum of about 6 miles (SE) from the shipment route. Less than 100 people live in the Santa Ynez Valley west of Lompoc.

APU ROUTE: VAFB - NMFA

2/9/62

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Figure 4-24. VAFB-PALC-2 Shipment Route

NAA-SR-MEMO-8147

Figure 4-25. New Mexico Ave - VAFB

USAF 3008

Figure 4-26. 35th St Near VAFB Surf Gate (Looking North)

USAF 3010

NAA-SR-MEMO-8147

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Figure 4-27. 35th St - Looking South Toward Santa Ynez River Causeway

USAF 5051 1963

1963

Figure 4-28. Santa Ynez River Causeway - Looking South

USAF 5050

3-1963

USN-LAL-10556-L

Figure 4-29. Community of Surf - Adjacent to Pt. Arguello Surf Gate

NMFPA - Surf Gate to PALC-2

After entering Navy property at the Surf Gate, the route follows the Coast Road south near the western boundary of NMFPA (Figure 4-30). The closest approach to the ocean is about 1000 ft, with most of the road lying 2000 to 3000 ft away. The route continues along the coast road for 3-1/2 miles and then turns left onto the access road to PALC-2, Figure 4-31. The trip is completed by traveling inland on the access road for 1/2 mile to PALC-2.

4.2.3 Accident Safeguards

Accident safeguards to be utilized during shipment of the power system from VAFB to PALC-2 are discussed below.

4.2.3.1 Design Safeguards

The void filler blocks-reflector assembly, shipping container, and monitoring equipment are the primary design safeguards provided. The prime function of the void filler blocks and shipping container is to protect the reactor from hazardous environmental influences during transport, with the monitoring equipment providing continuous cognizance of the environmental status of the power system.

4.2.3.1.1 Void Filler Assembly

The void filler blocks, Figure 4-32, are designed to keep the reactor subcritical under all types of external environmental influence when the beryllium reflectors are installed on the reactor. The filler blocks partially occupy the four control drum voids in the reflector and thereby positively prevent the drums from moving inward. The filler blocks will also maintain the reactor subcritical if the reactor is completely submerged in water or other neutron reflecting media (however, if water nondestructively replaces the NaK in the core, this subcriticality will not be maintained, Table 4-2).

Experimental design verification of these nuclear specifications were performed using simulated void filler blocks and the basic SNAP 10A reactor.⁶ The experiments indicated that the present design would maintain the reactor subcritical with full water reflection. Prior to use on the flight systems, an "as-built" nuclear verification test will be conducted with each set of void filler blocks.

The void filler assembly consists of: (1) four half-cylinder blocks which partially occupy the voids left in the Be reflector by the outward rotated

3-1963

Figure 4-30. Coast Road - NMFP

USN-LAL-10554-L

3-1963

Figure 4-31. PALC-2 Access Road

USN-LAL-10555-L

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Figure 4-32. Void Filler Blocks

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control drums, (2) two rectangular blocks, each of which join two of the half-cylinder blocks together, and (3) a plate fitted to the end of the core vessel. The enclosing structural material is 0.06 in. 304 stainless steel. The outer 1/2 in. of the half-cylinders is packed with natural boron powder to 20% of theoretical density. The remainder of the volume is void (air). The rectangular sections have the void volume on the outside surface and a similar boron layer on the inside (next to the reflector) surface.

Each of the four half-cylinder shells is made in two sections, a long section and a short section. A groove on the back, flat side of the short section assures that this section will clear the control drum adjustment screw when the section is in place. The short section is placed in the drum void. The long section is put into the void above the short section. Each of the rectangular blocks is made in two sections which, when joined, provide a channel for the passage of wiring. The rectangular blocks are secured to the Be reflector with four studs.

Although the primary design objective in the void filler assembly is to provide nuclear protection against potential environmental sources of reactivity additions, their placement in the drum voids also insures against accidental drum rotation. Two other devices which also prevent drum rotation are in place during shipment. These are the (1) keyed drum locking arms and (2) drum locking pins. These latter safeguards are intended primarily for operational phases after shipping when the void filler blocks have been removed.¹ They do, however, provide a back-up protection against accidental drum rotation during shipment.

4.2.3.1.2 Power System Shipping Container

This container is identical to the one described in 4.1.3.1.2.

4.2.3.1.3 Power System Shipment Monitoring Equipment

This equipment is identical to that described in 4.1.2.2.2 and 4.1.3.1.3.

4.2.3.2 Procedural Safeguards

4.2.3.2.1 Route Selection

The route for shipment of the power system from the SPTF to PALC-2 was selected on the basis of directness, road condition, and location, which is almost wholly in government controlled areas. Because of this latter feature, traffic control during shipment can easily be effected to any desired degree.

Most of the route traverses areas almost completely unpopulated, with the exception of the first 2 miles on VAFB and for a short distance through the settlement of Surf (see 4.2.2.6 for complete route description).

4.2.3.2.2 Method of Transport

Truck transportation was chosen as the most practical and the safest method for the short trip involved. The time of transportation may be selected to optimize highway safety with respect to weather, traffic conditions, etc. The presence of escort vehicles and personnel to effect traffic control will provide almost complete protection from unanticipated events that might result from the presence of other vehicles.

4.2.3.2.3 Procedures

A manual covering the procedures for both normal handling and abnormal events will be written and available prior to the time of shipment.¹⁸ This manual will define the countermeasures to be taken in reducing any potential hazard, should an accident occur. Responsibilities, as well as names and/or titles of those persons to be informed in case of an accident, will be specified. Instructions will be given for the cleanup of any debris in the area. Personnel will be thoroughly trained to recognize and properly handle hazardous situations which might credibly arise during shipment.

4.2.4 Potential Shipment Accidents

Potential accidents that could occur during shipment of the power system are described and discussed in the following section together with the safeguards which will minimize the probability of the occurrence of such accidents. The potential effects of these accidents on the power system are also evaluated.

4.2.4.1 Discussion of Potential Shipment Accidents

Since the mode of transportation is similar to that used for the Santa Susana - VAFB shipment, the potential shipment accidents are similar to those discussed in 4.1.4.1. However, one important difference does exist; the probability of any type of a two or more vehicle accident is reduced to a very small value, certainly beyond the point of credibility. This conclusion is based on the fact that all other vehicles will be barred from the route during the passage of the transporting truck. The possibility of an accident involving only the transporting truck, although highly unlikely, remains. To minimize this source of

potential accident, a thorough vehicle inspection (brakes, tires, steering gear, etc) will be performed prior to departure. The driver will be familiar with the route, making at least one trial run with everything in place except the power system. The distance involved, 10.5 miles, is about 1/15 of the SS - VAFB trip, and thus significantly reduces the opportunity for an accident due to such events as vehicle failure, driver fatigue, etc. A lower average speed will also be utilized, probably about 10 to 15 mph. Loss of vehicle control at these speeds is improbable. The only significant downhill grade encountered is just prior to leaving VAFB property (Figure 4-26).

In summary, it is concluded that during this shipment phase the probability of a two-vehicle accident is reduced essentially to zero. The possibility of an accident involving the transporting vehicle alone, while significantly reduced from the SS - VAFB shipment phase and of a very low probability, cannot be entirely eliminated. The potential effects of such accidents on the power system and the possible hazardous conditions which could result are discussed in the following section.

4.2.4.2 Potential Consequences of Transportation Accidents on Power System

The analysis presented for the SS - VAFB shipment (4.1.4.2) essentially applies here also, with two exceptions: (1) A large gasoline fire (e.g., collision with a tanker truck) is not considered possible. The only inflammable fuel present would be that in the fuel tank of the transporting vehicle, which will be kept at a minimum, (2) The beryllium reflector and the LiH shield are in place on the reactor in the power system shipping container. Unless the integrity of the shipping container is breached by the accident, no hazard can result from this source. Under the specified travel conditions, it is difficult to postulate a credible accident severe enough to cause the loss of this integrity. If it is somehow breached, the following possibilities exist:

4.2.4.2.1 NaK Fire

If the NaK lines are broken in an air environment, a fire will almost certainly result. The particulars are identical to those given in 4.1.4.2.1.

4.2.4.2.2 Lithium Hydride Fire

Based on the NaK fire source (see 4.1.4.2.2), a maximum of about 45 lb of LiH could burn, assuming unlikely rupture of its casing material and

fracture of the shield into smaller pieces. Although a larger fire could conceivably result (truck fuel, vehicle, structure, etc), complete consumption of the shield by fire appears highly improbable.

4.2.4.2.3 Beryllium Involvement

The potential fires are much too small for a significant hazard from this source (see 4.1.4.2.3).

4.2.4.2.4 Uranium Involvement

The reduced probability of long-term, high-temperature fires due to accidents in this phase of the shipment significantly decreases the likelihood of any airborne uranium release. Otherwise, the analysis presented in 4.1.4.2.4 applies.

4.2.4.2.5 Fission Product Inventory Involvement

As noted above for the uranium, the reduction in the fire severity possibilities further reduces the already negligible hazard from this source (4.1.4.2.5). In addition, further radioactive decay since the SS - VAFB shipment (a minimum of about 4 wk) will result in a reduction in the acceptance testing inventory (about 3 mc total, of which less than 0.1 mc is of the volatile elements I¹³¹ and Xe¹³³).

4.2.4.2.6 Nuclear Accidents

As with the SS - VAFB shipment phase, it is adjudged that the overall safeguards provided for the VAFB - NMFA shipment remove, beyond the bounds of credibility, the possibility of an accident resulting in reactor criticality. This conclusion is based on the consideration of the sequence of events which would be necessary for criticality to occur, as summarized below:

- a) A truck accident must occur.
- b) The accident must be severe enough to breach the water tight integrity of the inner shipping container.
- c) The breached container must be so located to allow flooding with water (or the power system must be released from the container into water).
- d) The nuclear protection of the void-filler-blocks must be forcibly eliminated without significantly distorting the core geometry,

or water must nondestructively replace at least a portion of the NaK within the core.

While the reflector, void-filler-block combination provides somewhat less nuclear protection than the shipping sleeve (see Table 4-2 of Appendix A) against homogeneous media, the shorter, better controlled route, and the general absence of such media along the route, compensate for this change. The only possible source of appreciable water encountered is at the bridge over the Santa Ynez River (see Figure 4-28). Particular care will be taken in the approach and crossing of this bridge during shipment and all other traffic will be strictly prohibited by roadblocks. The approach to the bridge is straight and level (see Figure 4-27). A truck accident at any other portion of the route, even assuming the improbable rupture of the shipping container and exposure of the power system, could not result in criticality. Therefore, it is concluded that any decrease in nuclear safeguards resulting from the substitution of the void-filler-block, reflector combination for the shipping sleeve is more than compensated for by the decrease in probability of a transporting vehicle accident which could expose the power system to the environment necessary for a criticality incident.

4.2.5 Maximum Credible Accident

4.2.5.1 Description

The maximum credible accident is assumed to occur as a result of a transporting vehicle failure and/or driver error. It is further postulated that the accident, somehow, causes the breach of the gas tight integrity of the shipping container, and that a NaK leak occurs, resulting in a metal fire. An evaluation of the potential hazards from such an event follows below.

4.2.5.2 Evaluation of Potential Consequences of MCA

4.2.5.2.1 NaK

With one exception, the evaluation presented previously in 4.1.5.2.1 is wholly applicable to this accident. Since a fire (other than of the NaK itself) of a much smaller magnitude is assumed in the present case, the initial height of rise of the airborne alkali oxides would probably be less. Therefore, Figure 4-33 gives the downwind concentrations in a manner identical to that in Figure 4-22, except that the upper limit of a ground level release (zero height of rise) is shown for comparison with the 50-ft cloud rise. As can be inferred from this figure, the oxide concentrations for cloud rises of less than 50 ft can be quite high

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Figure 4-33. Caustic Oxide Concentrations as a Function of Downwind Distance from a 30-Min Fire

for a 1000 ft or so directly downwind; however, the plume is relatively narrow (~65 ft from centerline to 1% of centerline concentration at 1000 ft downwind), and control of such areas this distance downwind for a short period of time would not be difficult.

4.2.5.2.2 LiH

The consumption of 45 lb of LiH shield material in a fire could produce an airborne source of up to 84 lb of Li_2O . In a manner similar to that described in the preceding paragraph, the downwind concentrations for a ground level release and 50-ft height of initial use are shown in Figure 4-33. As with the NaK fire evaluation, if very low release heights are assumed, relatively high air concentrations can occur for a few thousand ft downwind. However, no allowance has been made in either evaluation for less than 100% airborne release or subsequent ground fallout. Therefore, the values shown represent an upper limit and almost certainly are conservative by a factor of at least 2 to 5.

4.2.5.2.3 Uranium

A significant release of airborne uranium is not considered credible as a result of the postulated accident. However, Figure 4-23 may be used to estimate the downwind hazard if a hypothetical evaluation is desired.

4.2.5.2.4 Fission Products

Potential downwind exposures from any residual fission product release are negligible. For example, if the entire I^{131} inventory were released (about 70 μc) at ground level, the potential thyroid dose 50-ft downwind would be about 34 mrem.

4.2.6 Summary and Conclusions

There are two primary differences between shipment of the power system from the SPTF at VAFB to Palc-2, NMFA, and the previous shipment from Santa Susana to VAFB: First, the shipping sleeve used in the latter phase is replaced with the void-filler-block, reflector combination and the LiH shield is in place beneath the reactor. Second, the trip to PALC-2, which is only about 1/15 the distance from SS to VAFB, lies almost wholly on government controlled land, thereby permitting complete traffic control during shipment. As a result, the probability of a vehicle accident, and particularly one of major severity, is greatly reduced. Nevertheless, vehicle accidents are always possible in spite

of precautions and it is conceivable that one could occur during shipment of the power system to PALC-2. Such an accident, in the extreme, could possibly result in a relatively small fire (NaK, vehicle fuel) and cause considerable damage to the power system. Under adverse weather conditions, irritating downwind airborne concentrations of alkali oxides from burning NaK and LiH could exist for a 1000 ft or so for periods of up to about 30 min. Other potentially toxic materials present — uranium, beryllium, and residual fission products — are evaluated as negligible hazards under the conditions of the accident postulated as maximum credible.

Although somewhat less protection against accidental reactor criticality, resulting from environmental sources such as water, is provided by the void-filler-block, reflector combination, than is provided by the shipping sleeve, the possibility that an accident will ever proceed to the point where such a device is required to maintain subcriticality is greatly reduced. Thus, the overall safeguards provided against such an event are at least as great as in the former shipment phase and accidental criticality is evaluated as incredible.

In view of the small probability of an accident, and the limited magnitude of any resultant hazard should an accident occur, the safeguards provided for the power system shipment appear to be more than adequate.

APPENDIX A. SNAP 10A REACTIVITY VALUES

Table 4-2 presents a summary of the reactivity status of the SNAP 10A reactor with various configurations and environments. These values are primarily based on experimental measurements ⁽⁵⁾⁽⁶⁾⁽¹³⁾ but some analytical extrapolations have been made in certain instances. These latter cases are identified in the table by a range of reactivity values which represent the error limits of the calculation. Prior to shipment, further experimental determinations will be made with each set of void-filler blocks and shipping sleeve to be used.

In the cases of human body reflection, three situations are identified:

1. Single human body reflection - standing adjacent

This configuration corresponds to a single person standing against the reactor (sleeve, reflector). The values are based on paraffin block experiments.

2. Single human body reflection - wrap-around

This estimate is based on the maximum possible reactivity worth of a human body even assuming intentional motives; that is, an absolute upper limit for one person. The basic assumption made is that a human body is worth 1/3 that of infinite radial water reflection.

3. Maximum human body reflection - wrap around

This case is an extension of 2. above, without limit to the number of persons (nominally, at least three), that is, an absolute upper limit to the reactivity that any number of people can add to the system with any positioning of bodies.

TABLE 4-2
SUMMARY OF SNAP 10A REACTIVITY VALUES (\$)

Side 1	Side 2	In Air	Single Human Standing Adj.	Single Human Wrap Around	Maximum Human Wrap Around	Infinite Water Reflection	
						Nak in Core	H ₂ O in Core
sleeve	sleeve	-18.00	-17.70	-16.00	-12.00	-8.80 ± 1.20	- 3.00 ± 60
bare	sleeve	-19.10	-18.80 -18.00*	-17.10 -12.10*	- 5.60	-2.20 ± 1.90	+ 5.60 ± 1.90
reflector with void- filler blks	sleeve	-11.30	-11.00	- 9.30	- 6.80	-4.60 ± 1.90	+ 2.70 ± 2.60
reflector with void- filler blks	bare	-12.40	-12.10 -11.30*	-11.40 - 5.40*	- 0.40	-2.00 ± 1.60	+ 9.30 ± 2.30
reflector with void- filler blks	reflector with void- filler blks	- 4.60	- 4.30	- 3.60	- 1.60	-1.50 ± 25	+ 7.00 ± 1.50
bare	bare	-20.30	-19.20	-13.30	+ 0.70	+4.40 ± 0.80	+11.70 ± 1.50

*Human on bare side of reactor

†Based on extrapolation to flight system reactor reactivity. Will be shimmed to subcritical value if necessary.

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