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ACCEPTANCE TEST FACILITY
SAFEGUARDS REPORT

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ACCEPTANCE TEST FACILITY SAFEGUARDS REPORT

Editor
W. H. HENEVELD

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DATE 11/19/18 BY *BOC*

Authors

P. L. SOSKE
A. S. OSTENSO
F. J. KAMENSKY Exempt from
SHELDON BERGER (per 7/24)

ON 10/10/71
BY ADMIN. DIV. OF DOJ
BY J. E. Sullivan DATE 4/27/71

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1. INTRODUCTION

1.1 PURPOSE

The purpose of this report is to describe the operation of the Acceptance Test Facility (ATF) and testing of SNAP 10A Auxiliary Power Units (APU) in the facility. A hazards analysis of the facility, with a discussion of maximum credible accidents and consequences, is included. The Acceptance Test program is presented along with those test procedures associated with the reactor operation. This report covers only the tests and operations to be conducted with SNAP 10A systems; acceptance tests of SNAP 2 and 8 systems, which will also be conducted in this facility, will be presented in an addendum to be published at a later date. A separate operation manual, presenting descriptions and detailed test procedures, will be issued prior to operation of the facility.

1.2 OBJECTIVES

The final product of the SNAP program is a compact, nuclear auxiliary power system in the nose cone assembly of a space vehicle. These units and their related components will be developed and tested within the SNAP project and assembled by shop and project personnel. The Acceptance Test Facility (Building 019) will provide for final assembly and adjustments, nuclear fuel loading, heat-transfer-medium loading, nonnuclear systems test, and nuclear criticality tests and calibrations of all proposed SNAP 10A units (Figure 1). The APU components will have been developed and tested in other facilities prior to arriving at the ATF. The APU and component subassemblies will be transported from the assembly facility to the ATF for final testing prior to delivery to the launch site.

1.3 ACCEPTANCE TESTING

The Acceptance Test program to be conducted in the ATF is presented in Section 4. Briefly, the test program is composed as follows:

1.3.1 Nuclear Tests

APU nuclear operations will be limited to criticality and zero-power experiments. The testing program will include control drum calibration and determinations of reactivity worths and temperature coefficients. Heat transfer

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Figure 1. Acceptance Test Building (Building 019)

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and nuclear system integration characteristics will be determined by the application of electrical heat. Power level during these tests will be limited to an increase of neutron countrate of four decades above the original criticality countrate. The reflector and control drum shims will be adjusted, if required, to provide the desired excess reactivity for the system.

1.3.2 Non-nuclear Tests

Non-nuclear testing will be initiated upon satisfactory completion and acceptance of the nuclear tests. Non-nuclear tests will be performed to demonstrate heat transfer system characteristics and reliability under design conditions. Since many non-nuclear tests will be conducted on a prototype system in the non-nuclear test facility, an extensive non-nuclear testing program is not required during final acceptance testing and will be confined to verification of previously recorded experimental data.

1.4 SAFEGUARDS SUMMARY

The ATF is designed to maintain safety requirements established by Atomics International and the AEC. To aid in safe operation of the facility and to minimize radiological hazards, all nuclear acceptance tests will be carried out in an underground vault. Testing of the reactor will follow controlled and supervised basic steps: loading the core with fuel, filling the system with NaK, and bringing the reactor to a zero power level. After successful completion of tests at zero power, the reactor will be shut down, the reflector-control sub-assembly removed, and a shipping sleeve installed in its place. The APU reflector and shield will then be packaged for shipment to the launch site.

The hazards analysis of the ATF and the operations to be conducted therein, consists of two parts, nuclear and non-nuclear. The maximum credible accidents and consequences for each part are summarized below.

1.4.1 Non-nuclear

The maximum credible non-nuclear accident is a NaK fire in the immediate vicinity of the core. This fire is assumed to occur at the completion of a zero power critical test (16-watt-hour burnup) with the maximum fission product inventory within the core. The temperature of the fire is sufficiently high (1650°F) to cause rupturing of the fuel element cladding and oxidation of the beryllium reflectors.

The maximum beryllium air concentration within the high bay area is about $12 \mu\text{gm}/\text{m}^3$. This concentration is six times greater than the maximum permissible concentration for full time exposure. However, it is allowable for short periods of time (~ 30 min) which is ample for either leaving the facility or putting on proper respiratory equipment.

The total integrated whole-body gamma exposure, resulting from the release of the volatile fission products accumulated during the zero-power run, is 0.014 rem. The corresponding thyroid dose is 1.8 rem. These values are well within the acceptable limits for an emergency exposure.

The maximum specific activity of uranium in the high bay area due to its vapor pressure at 1650°F is $6.5 \times 10^{-14} \mu\text{c}/\text{cc}$. This is negligible compared to its MPC value of $5 \times 10^{-11} \mu\text{c}/\text{cc}$.

1.4.2 Nuclear

The maximum credible nuclear accident is one in which one drum is continuously rotated in at its maximum speed of $0.5^\circ/\text{sec}$. On a cold, clean core, this would cause an excursion releasing 40 Mws of energy.

An examination of Table VII indicates that the consequences of this maximum credible accident are well below the acceptable whole-body exposure of 25 rem at the nearest site facility (1.6 rem) and site boundary (0.27 rem), and negligible at the nearest community. This is based on an instantaneous release of 2.5% of the volatile fission products (Xe, Kr, and I) and the subsequent downwind drifting of the radioactive cloud under strong inversion conditions. At these locations, the direct dose due to prompt neutrons and gamma rays would be negligible, since the reactor is assumed to be in the vault (some 10 ft underground) at the time of the excursion. These downwind doses assume no containment in the facility.

Within the facility itself, assuming total containment, the total integrated whole-body exposure is 8.1 rem with a thyroid dose of 64 rem for a 30-min residence time in the high bay. The direct dose immediately over the 4-ft concrete plug is 1.7 rem, due to both prompt neutrons and gamma rays. These values are, again, within the maximum acceptable limits of an emergency exposure.

Operation of the ATF will not constitute a hazard to operating personnel or to surrounding occupied areas outside the site area.

2. FACILITY

2.1 LOCATION

The Acceptance Test Facility is located near the north boundary of Atomics International's Nuclear Development Field Laboratory in Ventura County, California. Figure 2 shows the location of the facility in relation to the other nearby facilities on the site. The Field Laboratory, a part of North American Aviation Field Test Area, is approximately 30 miles west-northwest of Los Angeles. For further details see NAA-SR-7300, "Evaluation of AI Nuclear Development Field Laboratory as a Location for Reactor Facilities,"¹ covering the meteorological, drainage, geological, and seismic aspects of this site along with the population density of the surrounding area.

2.2 ACCEPTANCE TEST FACILITY (ATF)

The ATF is composed of two basic areas: a high bay housing the test and assembly area, and a low bay housing the office area, control room, and auxiliary equipment rooms. A fuel storage room is located adjacent to the south wall of the high bay. Figure 3 shows the floor plan of the building and location of major pieces of equipment. The building superstructure is of conventional steel frame and metal siding construction. Leak tightness for the structure is limited to ordinary weatherproofing considerations, because fission-product-containment capability has been integrated into the vacuum testing vessel.

High Bay The high bay area houses the space and equipment required for performing the functions of auxiliary power unit (APU) acceptance testing. The area is 45 ft wide by 80 ft long, with a clear floor-to-frame height of 32 ft. The shielded concrete test vault described in Section 2.6.2 is located in this area.

Component and equipment handling is provided by a motorized bridge crane with a capacity of 10 tons and a clear hook height of 25 ft above the floor. This crane provides handling facility over 75% of the usable high bay floor space.

Covered floor trenches connect the test vault with the control room and with the local control stations within the high bay area. These trenches will carry power and control wiring from the APU to appropriate stations in cable trays and rigid conduit.

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NUCLEAR DEVELOPMENT FIELD LABORATORIES
SANTA SUSANA

INDUSTRIAL PLANNING
MARCH 15, 1962

SCALE IN FEET

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DEPT. NO.	DESCRIPTION
003	ENGINEERING TEST BLDG. 10,775 SQ FT
005	ORGANIC LAB.
006	SODIUM LAB.
007	SODIUM STORAGE
008	INFLAMMABLE STORAGE
009	SGR-OMR CRITICAL EXPERIMENT FACILITY
011	WAREHOUSE SUPPORT
020	COMPONENT DEVELOPMENT HOT CELL
040	PROTECTIVE SERVICES CONTROL CENTER
043	SKID SHACK
053	FIRE DEPT. SERVICE BLDG.
063	ELECTRONICS SHOP
093	AE6 REACTOR BLDG.
143	SODIUM REACTOR EXPERIMENT 15,000 SQ FT
173	STORAGE BLDG.
183	MAIN AUX. FIRE PUMP BLDG.
273	PROTECTIVE CLOTHING STORAGE
283	PROTECTIVE CLOTHING STORAGE
293	CONSTRUCTION SHACK
313	CONSERVATION SHACK
323	GUARD BLDG. (CDHC)
333	TIME CLOCK BLDG.
343	GUARD BLDG.
353	ORGANICS REACTOR DEV. BLDG.
363	MECH. COMP. DEV. & COUNTING BLDG.
373	EXPERIMENTAL DEV. BLDG.
383	INSTRUMENTATION BLDG.
403	TRAFFIC DISPATCH BLDG.
413	SECONDARY PAD INSTAL.
500	GAS BOTTLE DOCK (NEAR BLDG. 011)
501	PARKING LOT NEAR BLDG. 007
502	PARKING LOT NEAR BLDG. 006
509	PARKING LOT NEAR BLDG. 009
510	PARKING LOT NEAR BLDG. 100
511	PARKING LOT AT MAIN GATE
520	PARKING LOT NEAR BLDG. 020
521	PARKING LOT NEAR BLDG. 011
523	PARKING LOT, KEWB & AE-6 AREA
524	PARKING LOT NEAR SNAP AREA
535	PARKING LOT NEAR BLDG. 035
537	PARKING LOT NEAR SNAP
536	PARKING LOT NEAR BLDG. 036
540	PARKING LOT NEAR BLDG. 040
553	PARKING LOT NEAR BLDG. 353
573	PARKING LOT NEAR BLDG. 373
575	PARKING LOT NEAR BLDG. 375
583	CONSERVATION YARD
600	SEWAGE TREATMENT PLANT
606	SODIUM LAB. INSTRU. BLDG. "A"
607	SODIUM LAB. INSTRU. BLDG. "B"
611	PAINT SPRAY BOOTH CANOPY
612	MAINTENANCE
616	COOLING TOWER NEAR BLDG. 006
623	GUARD BLDG. AT MAIN GATE
624	FIRE TRUCK CANOPY NEAR BLDG. 040
633	REACTOR COOLING WATER PAD
643	REACTOR AIR FILTER STRUCTURE
654	INTERIM RADIOACTIVE WASTE
687	HELIUM BOTTLE STORAGE
693	ELEC. SUB-STATION NO. 1
703	WATER TOWER
704	ELEC. SUB-STATION (EDISON)
705	ELEC. SUB-STATION NEAR BLDG. 005
706	ELEC. SUB-STATION NEAR BLDG. 006
709	ELEC. SUB-STATION NEAR BLDG. 009
710	ELEC. SUB-STATION NEAR BLDG. 100
711	ELEC. SUB-STATION NEAR BLDG. 011
720	ELEC. SUB-STATION NEAR BLDG. 020
723	SODIUM CLEANING PAD
733	SODIUM CLEANING PAD
757	ELEC. SUB-STATION (NEAR 383)
763	ELEC. SUB-STATION NO. 3 (NEAR 063)
783	ELEC. SUB-STATION NO. 4 (NEAR 033)
806	TIMEKEEPING STRUCTURE
823	TIMEKEEPING STRUCTURE
836	TIMEKEEPING STRUCTURE
848	PAD AT BLDG. 373
853	PAD AROUND BLDG. 353
863	PAD AT BLDG. 363
864	MECH. EQUIPMENT SLAB
865	SODIUM STORAGE PAD
883	PAD AT BLDG. 363
885	PISTOL RANGE
886	SODIUM DISPOSAL PIT
893	PAD (AE-6)
894	PAD WEST CORNER BLDG. 143
895	PAD SOUTHWEST END BLDG. 143
896	PAD SOUTHWEST END BLDG. 143
897	HOT CELL PAD SOUTH WEST BLDG. 143
898	PAD NORTHEAST CORNER SRE

Figure 2. AI Nuclear Development
Field Laboratories

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Figure 3. Acceptance
Test Building Floor Plan
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Equipment access to the high bay is provided through 14-ft by 20-ft roll-up doors at each end of the building. These doors will pass the APU nose cone in a vertical position on ground transport equipment. In addition, personnel doors adjacent to the roll-up doors will provide for additional access to the high bay. All outside high bay doors will be kept locked during fuel loading. Keys to these doors will be in the possession of the shift engineer.

Only two fueled APU systems and one nonfueled system will be permitted in the area at any one time. The movement and control of these systems within the area is discussed in Section 2.8.

Low Bay The low bay area (80 ft by 28 ft by 10 ft eave height) houses the facility and testing support equipment, control room, office space, instrumentation repair and storage room, change room, and sanitary facilities. Traffic between the two bays is through the change room. The door into the control room is for emergency exit only.

Control Room The control room occupies about 840 ft² of the low bay area. A description of the instrumentation contained in this room is presented in Section 2.3.3.

Change Room A change room 10 ft wide by 11-1/2 ft long, is located adjacent to the high bay. All personnel traffic to the high bay will be routed through this area. This room will contain a lavatory, hand-and-foot radiation monitor, and lockers to accommodate the facility personnel. Normal toilet facilities are provided in a separate room adjacent to the change room. The change room is also equipped with a floor drain and "hot" sink which discharge to the waste holdup tank.

Instrument Repair and Equipment Storage This area (11-1/2 ft by 13-1/2 ft) is used for the storage of small parts and equipment required for the functional operation of the facility. Work benches are provided for routine maintenance and repair of instrumentation components.

Office Area The office area (11-1/2 ft by 29-1/2 ft) provides desks and cabinet space for four engineers and the supervisor.

Mechanical and Electrical Equipment Room This room (20 ft by 28 ft) is located at the north end of the low bay and houses the building utility equipment.

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2.3 ATF SERVICE SYSTEMS

2.3.1 Fire and Radiological Protection

A number of systems installed in the Acceptance Test Facility provide radiation warning and fire protection to personnel working in the facility and adjacent areas. These systems are:

- a) Area Radiation Alarm System (RAS)
- b) Facility Radiation Detector-Monitor System (RD)
- c) Vent Air Filter
- d) Vent Radiation Detector-Monitor
- e) Fire Detection and Control System.

The locations of these units are shown in Figure 4.

2.3.1.1 Radiation Alarm System (RAS)

To ensure personnel safety in and around radioactive areas, a general area alarm system has been installed. This system, RAS, consists of G-M radiation detectors located around the facility (Figure 4) with flashing lights and a siren mounted outside the building in a conspicuous place. A control console in the AI Control Center¹ (Building 040) monitors the whole RAS system.

The RAS circuit is set to alarm at a radiation level in excess of 20 mr/hr. Should the activity levels at the ATF exceed this amount, the RAS detectors will initiate the siren on Building 013 and start a flashing red light and siren on top of Building 019. The alarm also lights an annunciator in the ATF control room.

When the RAS siren is sounded, the facility is evacuated, according to established procedures, to emergency assembly area No. 4 (Section 5.7).

2.3.1.2 Radiation Detector-Monitor System (RD)

The RD system monitors the background radiation level at five locations in the ATF. This system consists of G-M type ionization chambers with read-out and recording instruments located in the control room. When the preset radioactivity level is exceeded at any of the detectors, the appropriate annunciator will be activated in the control room. The subsequent action will be determined by the facility supervision.

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Figure 4. ATF Protection Systems

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2.3.1.3 Vent Air Filter

The output of the vacuum system is discharged through a roof level vent equipped with an absolute filter to prevent the escape of radioactivity from the system. When the filter becomes loaded to the point where the pressure drop exceeds 1.5 in. of water, a ΔP monitor activates an alarm in the control room.

2.3.1.4 Vent Radiation Detector

A vent radiation detector will continuously monitor the test vault exhaust system gases for radioactivity. A constant-volume gas sample will be withdrawn with an isokinetic probe and circulated through a gas counting chamber where the activity is measured by six G-M tubes. The probe pumping system has an electronic flow detector that adjusts the pumping speed to maintain a constant flow rate through the measuring system. This compensates for the increased pressure drop due to filter loading. The vent monitor has an adjustable activity level alarm which will be set at approximately twice background rate. A relay contact in this circuit is a series interlock in the vacuum outlet valve system and will close the valves on high radiation level. This system also contains a rate detector to initiate visual and audio alarms when the countrate change exceeds 75 counts/min/min. The activity level is recorded on a strip chart recorder.

2.3.1.5 Fire Protection Systems

The ATF fire detection and control systems consist of rate of rise heat detectors, warning horn, manual fire alarms, and portable extinguishers. There will be four types of fire extinguishing equipment used in the facility:

- a) Automatic wet pipe sprinklers
- b) Portable high pressure CO₂
- c) Portable dry chemical, MET-L-X-30
- d) Portable water pump cans

The automatic wet pipe sprinkler system is used in the low bay area. These sprinklers are the fusible-link type.

Activation of this system sounds the fire warning horn. Operation of the system or the warning horn requires immediate notification of the Fire

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Department, as operating personnel are not allowed to turn off any fire protection system. All fire control equipment is maintained and inspected by the Fire Department.

Fire protection in the high bay area is limited to rate of rise heat detectors and portable CO₂ and MET-L-X-30 extinguishers to eliminate the presence of water in this area. Water grates are installed in each high bay entrance to prevent water from other areas from entering the high bay. High bay fire detectors will activate the fire warning horn only, which is audible throughout the adjacent area.

Manual fire alarms are located at each outside entrance to the facility and will sound the fire warning horn when activated.

The locations of the various fire protection systems are shown in Figure 4.

2.3.2 Building Ventilation

The building ventilation system (Figure 5) provides a separate air supply for the high and low bay areas. The high bay is supplied with 11,000 cfm of temperature controlled air by air handling unit No. 1 which maintains pressure in the high bay positive with respect to the outside atmosphere and negative with respect to the low bay. High bay and low bay pressure difference is monitored by a differential pressure indicator located in the control room.

Low bay air is supplied by air handling Unit No. 2 which draws in 1800 cfm fresh air to mix with 2700 cfm of return air.

The test vault receives air from the high bay (500 cfm) and exhausts through a high efficiency filter to the vent. Exhaust fan No. 1 maintains the test vault at a negative pressure with respect to the high bay.

The fuel storage vault is equipped with a separate exhaust fan and high efficiency filter and exhausts to the outside air. Pressure is maintained negative with respect to the high bay.

All ventilation ducts which pass through partition walls contain fire dampers equipped with fusible-link-type controls. Access doors will be provided.

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Figure 5. ATF Ventilation System

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In the event of an incident involving airborne contamination the high bay ventilation system will be shut down by the console operator at the console.

2.3.3 Control Room

The control room is located adjacent to the west wall of the high bay area and contains the instrumentation and controls necessary for the performance of the acceptance tests on fueled systems. The console and instrumentation racks are of modular construction and are interconnected with the reactor via covered floor trenches. Figure 6 shows the instrumentation racks and console.

The control room instrumentation is composed of four groups of racks and the control console. The bank of four racks on the left contains the nuclear monitoring system; the center group of six racks contains the thermal checkout controls and data recorders. The vacuum system controls and monitoring instruments are contained in the three racks on the right. At the rear of the control room are three racks containing the facility and area radiological warning systems. Filters and blowers are installed in all racks to provide filtered air to the components.

The following monitors and controls are located on the reactor control console:

- a) Drum drive control and selector switch
- b) Coarse and fine drum position indicators and fine drum indicator selector switch
- c) Master and individual drum scram switches
- d) Flux level, period, and log countrate meters
- e) Nuclear alarm interlock and scram annunciator panels
- f) Annunciator test and silence switches
- g) Drum limit lights
- h) Manual setback switch
- i) Facility evacuation emergency button.

Instrumentation for acceptance tests on nonfueled systems is provided by portable APU electrical test consoles located in the high bay area.

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Figure 6. Control Room Instrumentation

APU operating and output thermocouple data will also be recorded automatically on a data logger for rapid printed readout and permanent data storage.

2.4 NUCLEAR INSTRUMENTATION

2.4.1 Nuclear Channels

The nuclear instrumentation system will continuously monitor the radiation level and provide safe control of the reactor from initial loading, through startup, to a zero-power level. The system consists of four channels of neutron detectors and a gamma detector channel, an annunciator, scram, bypass, and interlock system, and a drum drive control system. A Pu-Be source will be installed outside the core vessel to provide a neutron flux for the nuclear detectors during all approaches to critical. During fuel loading a 5-curie source will be used; a 1-curie source will be used during reactor startups.

Startup Channels The nuclear startup channels (Channels I and II) will each use a dual-range fission chamber. With each fission chamber will be a preamplifier, time base generator and scaler, counter and printer, and count-rate recorder. A countrate meter and a period meter will be operated by either one of the startup channels. Both startup channels will have period trip scram adjustments, with a minimum allowable period of 10 sec.

Intermediate Channel The intermediate, or Log N channel will use an uncompensated ionization chamber. The accompanying intermediate channel instrumentation will consist of a power supply, a Log N period amplifier, a period recorder and a Log N recorder. This channel will provide signals for the 10-sec period and 120% operating level scrams.

Control Channel The control channel uses an uncompensated ionization chamber similar to the intermediate channel. It will contain a power supply, linear micro-microammeter, linear recorder, and an electrometer which will continuously follow the reactor power level rise. The scram level in this channel will be set at 100% of full scale on each range. A mechanical stop will be installed on the range selector switch at the maximum (scram) level to prevent switching to the high current scales. An auxiliary battery power supply is included to provide power to this channel in the event of a building power failure.

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Safety Channel

The safety channel, a backup channel, will use a sodium iodide (NaI) scintillation crystal with a photomultiplier tube (Dumont type 6291).

This detector will monitor gamma radiation, providing a high-gamma-level scram signal at 120% power level. This channel will also provide continuous monitoring of the reactor during shutdown periods. The accompanying instrumentation will include a power supply and alarm amplifier.

The total response time of each of the five channels is approximately 300 msec, including the control drum scram times. This will be verified prior to operation of the facility. The minimum nuclear instrumentation required for reactor operation will be one startup channel, Log N, and the control channel.

All detectors are monitored for B+ voltage. Loss of B+ will activate the instrumentation malfunction alarm (Table I).

2.4.2 Detector Locations

All detectors will be located on a stand in the vacuum chamber with the exception of the gamma channel (channel No. 5). The gamma scintillator will be located on the wall of the test vault. A diagram showing chamber locations is presented in Figure 7.

The Log N, Linear, and Gamma Channels will provide scram signals on high reactor flux. All scram signals will originate in the respective amplifiers. The scram settings will be determined experimentally. After the settings have been adjusted, the chamber shall not be relocated.

Each chamber will be bolted permanently to its experimentally determined position. The chamber positions will be confirmed by check sheet prior to installing the shield blocks. These measures will prevent indiscriminate chamber repositioning.

2.4.3 Test Drum Drive Instrumentation and Control

The test drum drives are controlled from the nuclear console utilizing the schematic illustrated in Figure 8. One manual control lever is provided for the normal in and out motion control of all four control drums. The drum to be moved is selected by a selector switch. The use of a single drum control

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NOTE

X = STARTUP CHANNELS
 O = CHANNELS III AND IV

Figure 7. Detection Chamber and Source Locations

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TYPICAL CLUTCH CONTROL

Figure 8. Control Drum Drive Schematic

provides an interlock to prevent the inward motion of more than one drum at a time. An additional switch is provided to drive all four drums outward simultaneously.

Key switches have been provided to lock out the power to each drum motor separately. These switches provide an independent control apart from the selector switch on the console and can limit the drum drive capability to a single drum.

The drum positions are monitored by three position-indicating systems. All four drums are monitored continuously by a coarse position indicating system with an accuracy of $\pm 0.5^\circ$ from 0 to 180° . A precision indicating system will monitor the position of any two drums selected, one of which is always the drum selected by the drum drive selector switch. The precision indicating system is read out on digital indicators with an accuracy of $\pm 0.10^\circ$ from 0 to 180° . The full in and out positions are indicated by lights actuated by limit switches. The acceptance test drum drive system is described in Section 3.4.2.

A scram timer will be integrated into the system to measure the scram time of each individual drum. The scram time of all four control drums from any position to their least reactive position is approximately 300 msec.

2.4.4 Annunciator System

The annunciator system is composed of audio and visual alarms which indicate malfunctions in the reactor system. When activated, the annunciator sounds an alarm and flashes a labeled display light indicating the fault. The alarm can be silenced but the display will remain lighted until the fault is corrected. Push-to-test buttons are provided for a display lamp test.

Two groups of annunciator panels will be installed: red panels to indicate scram conditions and amber panels to indicate alarm or warning conditions. A list of each alarm or scram condition with its activation level is shown in Table I.

2.4.5 Interlock and Bypass Systems

The interlock system will consist of a series of relays and conditions which must be satisfied before startup can be initiated. The system is shown in Figure 9. The condition of each interlock is indicated by a visual display in the control room.

TABLE I
ANNUNCIATOR PANEL

Panel	Set Points
<u>SCRAMS</u>	
1. Period Channel I	10 sec
2. Period Channel II	10 sec
3. Period Channel III	10 sec
4. Level Channel III	120% operating level
5. Level Channel IV	100% range full scale
6. High Gamma Channel V	120% operating level
7. Spare	-
8. Earthquake	VII Mercalli (modified)
9. Hydraulic hoist up	Off lower limit
10. Vault cover open	Open
11. Manual scram	Push
<u>NUCLEAR ALARMS</u>	
12. Instrument malfunction	Loss of B+
13. Spare	
14. Period Channel I, II, or III	25 sec
15. Period Setback I, II, III*	15 sec
16. Flux Level Channel IV	70% of range full scale
17. Reactor Outlet Temperature	1050°F
18, 19, 20. Spare	-
<u>THERMAL ALARMS</u>	
1. NaK Heater Current (Fine Controller)	0
2. Heater Shutdown	No NaK flow
3. NaK heater temperature (TRC-2)	1050°F
4. NaK Heater Current (Coarse Controller)	20% low
5. APU NaK flow	0.5 gpm
6. APU instrument compartment temperature	150°F
7. Expansion compensator No. 2	10 psi
8. Expansion compensator No. 1	10 psi
9. Thermal converter temperature	1025°F
10. NaK heater temperature (TRC-1)	1050°F
<u>VACUUM ALARMS</u>	
1. Vacuum vessel cooling water flow (low)	80 gpm
2. NaK leak detector	ON
3. Loss of vacuum	20 microns pressure
4. Cold trap temperature	80°F
5. Stack filter ΔP	1.5 in. of water
6. Vacuum tank coolant outlet temperature	100°F
7. Vacuum pump coolant flow	7 gpm
8. Vacuum pump coolant temperature	100°F
9. Vent Monitor	Twice background
10. Vacuum tank pressure	20 psig

*A setback drives out all drums until the alarm condition is relieved.

Most interlocks will have bypass capability. The bypass system will consist of a series of key-operated switches which can bypass an open interlock. Each switch will have a red display light to indicate its condition. There will be eight different bypass keys to operate the 18 interlocks. Each key will operate the specific switch or switches indicated in the Bypass-Interlock Diagram (Figure 9) and cannot be removed with the switch in the bypass condition. As shown, it is only possible, for example, to bypass one of three nuclear level channels and two of the three period channels at one time. The use of all bypass keys will be administratively controlled by the Shift Engineer.

2.5 THERMAL CHECKOUT

2.5.1 General

The purpose of the thermal checkout is to test the APU near the operating temperature, to establish that the power output and operation are within design limits and that the APU instrumentation functions reliably at these temperatures. During these tests the reactor will be operated at the zero-power level. External heat will be applied to raise the NaK temperature to 990°F.

2.5.2 External NaK Heating System

An external NaK heating system of electrical heaters will be supplied to maintain the NaK temperature at the desired level. These heaters will be controlled by a 150-kw saturable reactor whose output, in turn, is controlled by a recorder-controller. A thermocouple in the NaK loop will supply the signal for this controller. Total heater power consumption and the current in each power phase will be monitored and a low heater current alarm switch provided to actuate annunciator No. 4 and 1.

Another recorder will monitor the APU NaK coolant flow. Included in this circuit will be a pair of low-flow switches to activate alarm annunciator No. 5 and remove power from the NaK heater circuits when the flow drops to zero.

2.5.3 Auxiliary Systems

A resistive load bank, adjustable from 150 to 600 watts, will provide the output load for the APU thermal converter. Power dissipation is monitored by a watt-hour meter, and current, voltage, and power are recorded on a strip chart recorder.

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Figure 9. Bypass-Interlock Circuits

Control voltages and APU output voltages will be recorded on a 2-pen strip chart recorder. Automatic stepping switches will be installed to provide a profile recording of the APU voltages.

Another recorder using three 40-position stepping switches is capable of monitoring 120 APU thermocouple outputs.

An event monitoring recorder will be supplied to record ON-OFF events generated by the testing sequence.

2.5.4 Alarms and Interlocks

Trip amplifiers will be used to initiate alarms when off-design conditions occur. The following items are monitored by this system:

- a) Thermocouple voltages
- b) Expansion compensators, 1 and 2
- c) APU instrument compartment voltages.

A ten-channel annunciator with visual and audible alarms will provide warnings of alarm conditions. These conditions are listed in Thermal Alarms, Table I.

2.5.5 APU Electrical Test Consoles

2.5.5.1 General

After assembly of the APU and prior to fuel loading, an electrical inspection will be performed. The objectives of this test are to verify the operation of the following systems:

- a) Thermocouples and resistance thermometers
- b) Nuclear and flow instrumentation, position transmitters and limit switches, and accelerometers
- c) APU reset and prelaunch circuits
- d) APU startup and control circuits
- e) APU destruct, failure, and safety circuits.

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2.5.5.2 Description

The APU electrical test equipment will consist of portable consoles which will contain power supplies and test equipment to monitor APU performance, simulate AGENA commands and APU switch activated signals. These consoles will be located in the high bay area.

2.6 VACUUM SYSTEM

2.6.1 General

The vacuum system complex allows acceptance testing to be performed under simulated "space" conditions with the reactor at zero-power level. During the thermal tests, the reactor system will be operated at equivalent full power temperature by the application of external heat. Reactor loading, critical tests, and thermal tests will be performed in a vacuum system complex composed of a silo-type test vault, hydraulic lift, vacuum pumping equipment, and vacuum chamber (Figure 10).

2.6.2 Test Vault

Nuclear testing and calibration of the APU will be performed within a 12-ft-square, 39-ft-deep concrete vault. A hydraulically operated elevator with a capacity of 15 tons is provided in the vault for handling the APU. Removable concrete blocks totaling 4 ft in thickness provide shielding directly over the vault. An equivalent shielding of 4 ft of concrete is provided by concrete and earth adjacent to the vault at floor level. This reduces the dose rate directly over the center of the blocks to a calculated value of 2.5 mr/hr and 7.5 mr/hr over the annulus around the blocks at a power level of 16 watts.

The elevator will be interlocked to prevent inadvertent operation when the shield blocks are in place or while the vacuum chamber system is in operation. An additional interlock in the reactor control circuit scrams the reactor when the hoist is above its lower limit.

A sump and 10 gpm sump pump is provided at the bottom of the vault which will allow any water collected to discharge into the waste holdup tank. This is a 500-gallon tank which is housed in a subsurface pit adjacent to the south wall of the building (Figure 11). The tank is equipped with a liquid-level indicator which reads out in the control room facility panel. The "hot" lavatory and center floor drain in the facility change room also empty into the waste

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Figure 10. Vacuum System

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Figure 11. Waste Disposal System

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holdup tank. Health and Safety personnel will periodically monitor the contents of this tank and either dispose of the liquid as radioactive waste or valve to the site sewage system. Annunciator lights in the control room have been provided to indicate operation of the sump pump and sump level.

The probability of water entering the vault from the building proper is remote, as no facility water system is provided in the high bay area. However, the vacuum chamber cooling system will, if ruptured, release 180 gallons of water. This would result in only 1 in. of water in the vault.

2.6.3 Vacuum Chamber System

All nuclear and criticality testing of the reactor, and final acceptance testing of the assembled APU will be conducted within a coded vessel installed in the test vault. This vessel will provide secondary containment for the reactor. During APU acceptance testing, the vessel will be cooled for heat removal and evacuated to less than 10^{-2} mm of Hg to minimize heat loss by conduction.

The vacuum chamber system consists of the following basic elements:

- a) Vacuum chamber
- b) Vacuum pumping system
- c) Vacuum chamber cooling system

The vacuum chamber will be 9 ft in diameter and 17-1/2 ft in height. The chamber will be fabricated of carbon steel and will conform to ASME Boiler and Pressure Vessel Code, Section VIII, for Unfired Pressure Vessels, Section IX, Welding Qualifications, and Code Cases 1270 N, 1271 N, 1272 N, and 1274 N. APU reactor controls, wiring, and other connections which penetrate the vessel will be through sealed fittings.

The vessel will be provided with flanged separation joints to allow opening of the vessel for installation of the APU within the chamber and is designed to contain a 30-psi positive pressure as well as full vacuum. The vacuum chamber, pumping system, cooling system, and associated equipment will be tested for performance before operation.

The vacuum chamber will be tested to determine that the seal surfaces are seating properly. This will be done by testing for both in and out leakage

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Figure 12. Vacuum System (P&I Diagram)

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Figure 13. NaK Loading Cart

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from the chamber. These tests will minimize the possibility of an oxidizing environment in the chamber during acceptance testing at elevated temperatures.

Both tests will be conducted with the vacuum chamber isolated from the pumping system by the vacuum chamber isolation valves. The inleakage will be determined by a rate of pressure rise from operating vacuum. The maximum leak rate will be 0.35 standard cc/sec. The vacuum pumping system will maintain an empty chamber absolute pressure of less than 10^{-2} mm Hg at this leak rate.

The outleakage rate will be determined by a rate of pressure loss from 25 psig. The maximum acceptable leak rate will cause a pressure loss of 2.7 psi/8 hr. This will assure that all gaskets on the signal and control feed-throughs have seated properly.

The valve bonnets and pumping system piping will be leak checked with a helium leak detector at a pressure of one micron and all detected leaks repaired.

The vault is not sealed and no leak rate will be determined. A P and I diagram of the vacuum system is presented in Figure 12.

Vacuum Pumping System The vacuum pumping system will maintain a vacuum of less than 10^{-2} mm of Hg in the vessel and is composed of a first stage roughing pump followed by second and third stage Roots blowers. Pump discharge will exhaust through a bank of absolute filters and out the vent. Quick-closing fail-safe valves activated by appropriate signals from reactor instrumentation or stack monitor will isolate the vessel in event of an incident. These valves are the vacuum type, with a wedged double-plate seal capable of withstanding pressure from either direction. Two valves will be installed in series in the vacuum chamber pump-out line. The valves will be tested for closure rate and leakage. Both seal and bonnet leakage tests will be performed.

Vacuum Chamber Cooling The vessel will be cooled to an average wall temperature of 80°F by a closed-circuit water system. The coolant pipe loop will be copper tubing, thermally bonded to the vessel wall and insulated. A sump and sump pump are provided to remove water to a waste holdup tank in the event of a leak.

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2.6.4 Vacuum System Instrumentation

This instrumentation controls and records all information from the vacuum system complex. All controls and recording devices are located in racks in the control room.

Recording System — Vacuum Pressure The vacuum pressure is monitored by a continuous strip chart recorder. This recorder has two high-pressure alarm switches: Switch No. 1 actuates an annunciator (No. 10), and Switch No. 2 is a part of the vacuum pump startup interlock circuit. A vacuum gauge control and range selector unit supplies the input signal to the recorder. Two types of input transducers will be installed: (a) thermocouple sensors to cover the range from 1.0 to 10^{-3} mm of Hg and, (2) an ionization gauge for the range of 10^{-2} to 10^{-5} mm of Hg.

Vacuum Chamber Wall Temperatures Twelve chromel-constantan thermocouples will monitor the vacuum chamber wall and cold trap temperature. These will be recorded on a 12-point temperature recorder. The cold trap thermocouple also actuates annunciator No. 4 on a high temperature condition.

Vacuum Cooling System Data The vacuum vessel coolant flow will be monitored by the FAL-1 system. This consists of a pressure transducer with a remote dc power supply and strip chart recorder. The transducer output is also coupled to a flow alarm switch which activates annunciator No. 1.

The FAL-2 system monitors the coolant flow to the vacuum pumps and consists of a flow transducer and low flow alarm (annunciator No. 7). In addition, all three vacuum pumps have coolant flow visual sight gauges.

The coolant inlet and outlet temperatures are monitored by resistance thermometers whose output is recorded on a temperature recorder. The vacuum tank outlet signal also actuates the high temperature alarm annunciator No. 6. Five other local temperature indicators provide additional indication of the coolant temperatures.

NaK Leak Detector A spark plug transducer mounted in the vacuum system cold trap will be used for detecting NaK leaks from the APU. Two output circuits will be provided: one to activate annunciator No. 2 and the second as an interlock in the vacuum system outlet valve operating circuit.

Alarms and Interlocks The interlock system for the vacuum vessel isolation valves is shown in Figure 9. These valves are operated by an electrically controlled air supply. Loss of current from any of the interlock relays will result in complete closure of the valve within 10 sec of initiation of shut-down signal. A reserve air supply tank is included to supply air pressure to the valves in the event of a leak in the supply line.

Vacuum system alarm conditions are indicated by a 10-panel annunciator located in rack No. 18. The alarms in this system are listed in Table I, Items 1 through 10.

2.7 NaK HANDLING

The APU NaK loading will be performed by personnel trained in the safe handling of this material. All personnel involved in this operation will wear the recommended protective clothing for handling NaK. Fire fighting equipment and supplies will be on hand during the loading procedure.

NaK will be stored and loaded at the Liquid Metal Test Building¹ (023). It will be transported to the ATF in a fill cart (Figure 13) designed and developed for the loading of SNAP APU's. The fill cart will be attached to the APU lines and the system leak checked, purged with inert gas, and evacuated prior to introducing NaK into the lines. A drip pan will be placed under the NaK lines during NaK loading operations to prevent NaK from entering the water drainage system in case of a line break. The fill cart contains a heater, filter, and cold trap for NaK purification during the circulation cycle. The proposed NaK loading sequence is as follows:

- a) Fill the APU with clean NaK.
- b) Circulate the NaK through the APU and fill cart purification system while raising the system temperature to approximately 700°F.
- c) Dump the hot NaK into the NaK fill cart dump tank.
- d) Allow the APU to cool down.
- e) Repeat steps (a) through (d) one or more times until the system is clean (i. e., no plugging at ~20°F).
- f) Fill the system with clean NaK and seal.

After purification, the fill lines will be pinched off, welded by a continuous spot weld, and x-rayed to ensure a leak-tight system. The remaining NaK and fill cart will then be returned to Building 023.

2.8 FUEL STORAGE AND HANDLING

The fuel elements for one system will be stored in the fuel storage vault. The vault is adjacent to the southeast corner of the high bay and is accessible only from the high bay. Entry is controlled by metal tamper-proof doors and an approved combination lock. This room is of concrete block wall construction.

The fuel will be received in safe geometry containers (bird cages) with five elements in each bird cage. All fuel elements will be logged in, following the Standard Operating Policies of Atomics International. These containers will be placed along the south wall of the vault and will remain locked in the vault until required. Calculations have shown that containers with fuel can be stored in single rows along the wall with no significant interaction; that is, the solid angle subtended by the subcritical assemblies is less than 0.005 steradians.⁽¹⁴⁾

During the APU fuel loading operation, fuel elements will be checked out of the vault and placed in assigned positions in the core. This operation will be administratively controlled by the fuel loading check sheet.

To preclude the possibility of interaction between fully loaded systems, strict area controls will be in effect. The storage areas and APU system flow paths are illustrated in Figure 14. As shown in the diagram, the APU will be brought into the high bay and stationed in Area 1 for electrical checkout. The APU is then placed in the test vault, Area 2, loaded with fuel, and nuclear tests conducted. On completion of these operations, the APU is placed in its shipping container and stored in the primary APU storage area, Area 3. If a second APU is brought into the facility before the first has been shipped to the launch site, it will follow the same route to the test vault, and, on completion of fuel loading and nuclear testing, will be stored in the secondary APU storage area, Area 4, and locked in the wire cage. The cage key will be controlled by the Shift Engineer. Administrative control will be used to prevent the distance between the center line of the shipping container and the edge of the core in the secondary storage area from becoming less than 12 ft. Calculations have shown that, at distances greater than 12 ft, there is no significant interaction between

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Figure 14. Reactor Systems Controls

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two fully loaded systems; that is, the solid angle subtended by each assembly is less than 0.005 steradians.¹⁴

If a third nonfueled system is brought into the building, it will be located in the electrical checkout area. This unit will not be loaded with fuel until one of the loaded systems is removed from the building. The fueled systems will be identified by radiation tags placed 45° apart. This will provide a positive method for discriminating between fueled and nonfueled systems.

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3. AUXILIARY POWER UNIT (APU)

3.1 GENERAL DESCRIPTION

The SNAP 10A-flight system will consist of a SNAP 2 reactor as a heat source, an array of integral thermoelectric converter radiator units mounted on small tubes and a d-c conduction pump which transfers the heat from the reactor to these tubes by means of a liquid metal coolant (Figure 15). Other major components in the system include the radiation shield, the liquid metal expansion compensator and the reflector drum drive mechanisms. Electrical energy is produced by the thermoelectric process which occurs when a temperature difference is maintained between opposite faces of thermoelectric materials. The temperature differences are maintained by the liquid metals on the hot side and aluminum radiator dissipating heat energy to space on the cold side. The SNAP 10A system has been designed to provide 500 watts of continuous electrical power to the payload for a period of one year.²

3.2 REACTOR CORE

The reactor core is composed of 37 cylindrical fuel moderator elements 12-1/4 in. long. The elements contain a homogeneous mixture of zirconium hydride and U^{235} and are canned in a 1.25-in. OD Hastelloy N tube (Figure 16) which provides a cladding of 15 mils. The inside surfaces of the core element tubing and end caps are coated with a 3- to 4-mil layer of boron-free ceramic.

The 37 elements are arranged on 1.26-in. centers in a triangular array to form a hexagonal right cylinder core, 8 in. across the flats, 9 in. across corners, and 12 in. long. The fuel moderator elements are supported and held laterally by Hastelloy stainless steel grid plates. Figure 17 shows an exposed core and fuel elements.

Core Vessel The core tank is a cylindrical vessel constructed of 0.032-in.-thick, 300 series stainless steel. The core vessel exceeds the fuel rod length to form upper and lower plenum chambers. These plenums together with the grid plates provide the correct NaK flow distribution through the core.

Figure 15. SNAP 10A APU

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Figure 16. SNAP 10A Fuel Element

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Figure 17. SNAP 10A Reactor

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3.3 SHIELDING

A shield assembly (Figure 18a) is provided to protect the AGENA instrumentation from radiation damage. This is a shadow shield and is mounted below the reactor as shown in Figure 15.

3.4 CONTROL DRUMS

3.4.1 Flight Control System

The reactor core is reflected by beryllium with startup control effected by the angular rotation of four semicylindrical beryllium drums. In the flight system configuration, the four control drum elements are held in the out position by squib release detent pins. These squibs are fired by command when the system achieves a satisfactory orbit, thereby releasing the detent pins. Two of the control drums snap in to the full-in position under spring action. The other two control drums begin simultaneously stepping in at the rate of 0.5° per 150 sec by the two stepping motors. When the reactor reaches the operating temperature, insertion is stopped and a thermal controller assumes control. This device moves the two control drums to maintain a constant temperature level during the ensuing xenon transient (approximately 3 days at full power). Subsequent long-term control of the reactor will be supplied by the inherent temperature coefficients of reactivity and burnable poison, Sm_2O_3 .

3.4.2 Acceptance Test Control System

Following checkout of the flight control system on the nonfueled reactor, the flight drum motors are removed and four test drum drive units are installed. This drum drive system (Figure 19) is used for all nuclear tests and remains with the reactor until final packaging for shipment. The important differences between the test drum configuration and the flight system are summarized below:

- a) All four control drums are driven by reversible drive motors which will rotate the drums in at a maximum rate of $0.5^\circ/\text{sec}$ ($4^\circ/\text{degree}$ maximum per drum).
- b) Each control drum is coupled to the drive motor through a magnetic clutch and is spring loaded to drive the drum out upon loss of power to the clutch or the receipt of a scram signal.

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Figure 18a. SNAP 10A Shield Assembly

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Figure 18b. Void-Filler Blocks

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Figure 19. Test Drive Unit

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- c) A snubber will absorb the kinetic energy of the drum at the end of travel.
- d) A position indicating system will indicate the position of all four drums and IN and OUT limit switches will be installed.

3.4.3 Mechanical Protective Devices

A shipping sleeve and void-filler blocks will be installed periodically during the acceptance test program to ensure maximum safe condition of the reactor system at all times. These devices are described below:

Shipping Sleeve The shipping sleeve is a two-piece shield that is installed around the core as the reflector is removed. It protects the reactor from neutron reflection from any reflecting media and provides mechanical protection to the core vessel. Each half is always installed or removed in conjunction with the corresponding reflector section as described in Section 4.4.3, Figure 28. A similar sleeve, a weld sleeve, is described on page 117.

Void-Filler Blocks Two attachments, called void-filler blocks (see Figure 18b), are bolted to the reflectors so that the control drums are prevented from rotating inwards. The blocks also provide a mechanical interference to prevent the installation of the reflector with the control drum in the most reactive position. This is accomplished by having the reflector-handling-fixture bolt to the void-filler block assembly and not to the reflector itself.

Locks Each control drum can be locked in the least reactive position with a key lock attached to the reflector. The locking action is achieved by insertion of a stop on the reflector drum which prevents drum rotation. Keys to these locks will be under administrative control.

3.5 NaK HEAT TRANSFER SYSTEM

The heat transfer medium is NaK-78, a liquid metal (eutectic sodium-potassium alloy) which removes heat from the reactor and transfers it to thermoelectric converter units in the radiator. In flight, the coolant flows through the reactor entering at 885°F and leaving the core at 990°F. During the thermal tests at the ATF, the coolant will be heated to an average temperature of 990°F. Coolant flow and heat transfer sensors are shown in Figure 20.

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Figure 20. Process Flow and Instrumentation Schematic

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The coolant passes out of the reactor through an integral power source pump, then into two tubes which cross over the top of the core vessel, down along the sides of the core and shield, and into the converter upper manifold. From the upper manifold, the coolant flows down to the lower manifold through 40 converter tubes. From the lower manifold, the NaK flows back up into the reactor lower plenum chamber to complete the cycle.

The NaK coolant is pumped at a rate of 12 gpm by means of a d-c Faraday conduction pump, which derives its power from the Seebeck voltage developed in a thermoelectric converter mounted as an integral part of the pump (Figure 15). The coolant system also contains a volume expansion compensator which maintains a void-free coolant system under all expected temperature conditions. All portions of the heat transfer system contacting the coolant are fabricated of NaK corrosion resistant materials.

Radiator-Converter The radiator converter is composed of an array of stainless steel tubes on which the thermoelectric converter elements are mounted. Aluminum plates are used to radiate the excess heat to space while maintaining the proper temperature drop across the thermoelectric elements.

The aluminum radiator is fabricated in segments so that each thermoelement junction has an individual radiator. Alternate radiators are connected by a copper bar which provides an electrical connection between thermoelectric elements.

3.6 NUCLEAR CHARACTERISTICS

3.6.1 General

The nuclear characteristics of the SNAP reactors have been determined analytically, using the AIM-6 multigroup diffusion code with the Los Alamos 16 group cross-section library. The AIM-6 code³ is an expanded version of the WANDA code, incorporating a greater group structure and other features and operations which have been found desirable. The basic AIM-6 calculations have been found to agree with similar calculations using ZOOM⁴ and CURE.⁵ The operation of the SER (SNAP Experimental Reactor) and the SDR (SNAP Developmental Reactor) have provided a wealth of experimental information regarding the nuclear characteristics of these systems.

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3.6.2 Nuclear and Kinetic Parameters²Fuel Elements

Fuel alloy composition (wt %):

Uranium (before hydriding)	10.0
Uranium (after hydriding)	9.82
Zirconium (after hydriding)	88.38
Hydrogen	1.8
U ²³⁵ enrichment	93.15%
U ²³⁵ loading per element	124.3 gm
Hydrogen density in fuel	6.5×10^{22} atoms/cc*

Core Composition

Volume fractions:

Fuel alloy	0.828
NaK coolant	0.107
Hastelloy N tubing	0.051
Ceramic	0.011
Gap	0.003

Average densities:

Hydrogen	0.05382×10^{24} atoms/cc
Zirconium	0.02868×10^{24} atoms/cc
U ²³⁵	0.001151×10^{24} atoms/cc
U ²³⁸	0.000084×10^{24} atoms/cc
Sodium	0.000528×10^{24} atoms/cc
Potassium	0.001142×10^{24} atoms/cc
Hastelloy N	0.45 gm/cm ³
Hydrogen-to-U ²³⁵ atomic ratio	47.5
Total U ²³⁵ in core	4.6 kg

Core Reactivity Effects

For small uniform changes at full loading, the following reactivity values exist:

Hydrogen	+64¢/% change in hydrogen
U ²³⁵	+11.3¢/% change in U ²³⁵

*A limited number of elements hydrided to $6.0 \pm 0.1 \times 10^{22}$ will be available for use in the core.

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Zirconium	+15.6¢/% change in zirconium
NaK	+0.37¢
Central fuel element	+\$2.79
Edge fuel element	+\$1.60
Shield	+\$0.35

Kinetic Parameters

Prompt neutron life time	6.5×10^{-6} sec
Effective delay fraction:	
Fission neutrons only	0.0079
Fission and photo neutrons	0.0082
Fuel temperature coefficient	-0.10¢/°F
Total temperature coefficient	-0.22¢/°F
Power coefficient	-0.4¢/kw

Power Distribution

Total peak-to-average ratio	1.93
Radial peak-to-average ratio	1.31
Axial peak-to-average ratio	1.47

3.6.3 Reactivity During Reflector Assembly

The detailed changes in reactivities associated with the removal of the shipping sleeve and the installation of the reflector have been calculated to determine the safety margins during this operation. These values are shown in Table II. The reactor is at least \$4.30 subcritical during normal reflector installation.

3.6.4 Control Drum Worth

The reactor is controlled by four drums located in the 2-1/8-in.-thick beryllium reflector. Each drum has a predicted total reactivity worth of \$2.00. The integrated reactivity for each control drum as a function of its angular position is presented in Figure 21. Reflector shims will be provided to adjust the reactivity to the desired value. Table III shows estimated reactivities for various shim and drum configurations in the orbital condition. With the configurations shown the drum worth varies from \$1.87 to \$2.19.

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Figure 21. Drum Worth Curve

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TABLE II
REACTIVITY VALUES

Condition		Reactivity (\$)
Right Side	Left Side	
Sleeve	Sleeve	-18.00
Bare	Sleeve	-19.10
Be + void filler	Sleeve	-11.30
Be + void filler	Bare	-12.40
Be + void filler	Be + void filler	- 4.60
Vault		+ 0.05
Bare reactor in air		-20.30
One human adjacent to reactor, (void filler in place on reactor)		+ 0.30
One human adjacent to reactor, (no void filler in place, all drums out)		+ 0.35

TABLE III
CORE REACTIVITIES (\$) FOR SHIM AND DRUM CONFIGURATIONS

Number of Drums Inserted	Number of Complete Shim Sets			
	0	1	2	3
4	+1.93	+2.46	+3.00	+3.54
3	+0.06	+0.48	+0.92	+1.35
2	-1.81	-1.50	-1.16	-0.84
1	-3.68	-3.48	-3.24	-3.03
0	-5.55	-5.46	-5.32	-5.22

3.6.5 Shutdown Mechanisms

Two possible shutdown mechanisms exist during any SNAP 10 excursion produced by a ramp insertion of reactivity. The primary effect which produces a decrease in the excess reactivity is the prompt negative temperature coefficient ($-0.1\text{¢}/^{\circ}\text{F}$). In all cases, the prompt temperature coefficient will turn

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over the initial rise in power. As the zirconium hydride fuel alloy is heated, the internal pressure in the fuel element increases exponentially. Figure 22 shows the dissociation pressure of ZrH_2 as a function of temperature and also the rupture pressure of the Hastelloy N cladding as a function of temperature. It can be seen from this figure that at temperatures in excess of $1550^{\circ}F$ the dissociation pressure of the ZrH_2 is sufficient to cause bursting of the fuel element cladding. After the cladding ruptures, hydrogen will be evolved from the fuel elements, at approximately 10^{-3} lb/sec from the core. As hydrogen is carried out of the core, reactivity is reduced at the rate of approximately 3.5¢/sec until the reactor is irreversibly shut down.

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Figure 22. Cladding Rupture Conditions

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3.7 SYSTEM PERFORMANCE SUMMARY

A summary of the SNAP 10A system operating characteristics and parameters for the orbital condition is presented in Table IV.

TABLE IV
SYSTEM PERFORMANCE SUMMARY

<hr/> <hr/>		
Electrical Output		
Initial		585 watts
Year end		525 watts
Minimum voltage		28.5 volts
System Efficiency		
Initial		1.9%
Year end		1.7%
Reactor Thermal Output		33.6 kw
Temperatures		
Reactor outlet		990°F
Reactor inlet		885°F
Thermoconverter hot junction (average)		900°F
Thermoconverter cold junction (average)		620°F
Radiator (average)		615°F
NaK Coolant Flow Through Reactor		12 gpm
Number of pumps		1
Nominal system pressure		≤ 5.0 psia
System pressure drop		0.7 psi
Number of control drums		4
System weight objective		875 lb
Converter Radiator		
Area		62 ft ²
Number of radiators		1540
Average thickness		0.0585 in.
Effectiveness		0.95
Emissivity		0.85
Absorptivity		0.20
Radiation dose at payload during year		10 ¹² nvt, 10 ⁷ r
System Overall Dimensions		
Length		128.5 in.
Diameter at large end of converter		49.5 in.
Diameter at small end of converter		23 ¹³ /63 in.
<hr/>		

4. ACCEPTANCE TEST PROGRAM

4.1 GENERAL

SNAP 10A systems are received in Building 019 as a group of sub-assemblies. The acceptance tests and final assembly operations will be conducted as outlined in this section. No final assembly operations will be performed on the APU unless the condition (including reactivity and shut down margin) of the APU has been verified experimentally, and no tests will be conducted on the APU unless it is certified to be in the proper condition for these tests. Figure 23 shows a flow diagram of test and final assembly operations on the SNAP 10A subassemblies after arrival of the ATF. This sequence applies only to APU systems that are to be sent to launch facilities.

4.2 SEQUENCE OF OPERATIONS

4.2.1 Receipt of Subassemblies

The acceptance of the SNAP 10A subassemblies is the initial step in the acceptance test and final assembly program of each APU. The items to be received are:

Low Temperature Instrumentation and Equipment This is a group of items that will sustain damage from either elevated temperatures or temperature cycling. The instrumentation consists of accelerometers to be used on ascent monitoring, and the equipment includes various temperature shut down devices for end of life.

Reflector Flight Configuration The reflector with associated flight hardware will be received in its special shipping container.

APU Assembly Complete Except for Fuel, Reflector, Core Cap, Pump, and Shield The APU will be received in its handling fixture and mounted on the APU transport dolly. The APU will be logged as received, raised off the dolly, and placed in the physical and electrical inspection area in the southeast corner of the high bay.

Fuel The fuel elements will be received in safe geometry containers. They will be logged as received in accordance with AI standard SS accountability procedures and stored in the fuel storage vault.

Figure 23. Acceptance Test Flow Diagram

Core Cap and Pump The core cap and pump assembly will be logged in and stored in its allocated station.

Thermal Shield The thermal shield will be logged as received and stored in its allocated station.

4.2.2 Test and Assembly Operations

After the various subassemblies have been received and stored in their proper stations, the operations shown in Figure 23 follow. These tests and final assembly operations are regulated by detailed procedures which are a part of the operations manual, but separate from the facility operations procedures. The following operations will be performed.

The APU subassembly will be physically inspected to determine that the APU geometry is in accordance with the design criteria and general component appearance.

An electrical and instrumentation check will be conducted to ensure continuity, proper circuit resistances, and proper location of sensors.

The reflector assembly will be removed from its shipping container, inspected for physical damage, and inspected electrically for continuity and circuit resistances. It will then be installed on the APU subassembly.

The orbital startup and control circuitry will be functionally tested in the startup sequence test. The AGENA vehicle and APU operating functions will be simulated to allow the APU to go through the simulated normal startup and operation as well as all of the failure modes.

The flight reflector control drives are removed and stored in their proper station, and special test drum drive kits are installed on the reflector. The vacuum chamber is leak checked to ensure containment during nuclear operation.

The APU is installed in the vacuum chamber and two fission chambers are mounted on the stand. A 5-curie neutron source is mounted adjacent to the core vessel.

The nuclear instrumentation functional checks, control drum position calibrations, and alarm and scram checkouts are performed.

The fuel loading-dry critical operation is performed (Section 4.4.2).

The filler blocks and locks are installed and reflectors replaced with the weld sleeve (Section 4.4.3).

Core cap, pump, and associated NaK line welds are made, leak checked, and inspected.

The reflector is installed in place of the shipping sleeve, and the filler block and locks are removed (Section 4.4.3).

The vacuum chamber is sealed, the shield blocks installed, and a nuclear critical check performed, to determine if reactivity changes have occurred during welding operations.

The reflectors are replaced with the shipping sleeve.

NaK is loaded and a hot circulation and continuous purification performed to reduce system contamination.

The shipping sleeve is removed and the reflectors installed.

The APU is sealed in the vacuum chamber, and wet critical and nuclear acceptance tests are completed (Section 4.4.4). These tests will ensure that the proper excess reactivity is available for space operating conditions and orbital startup control. The thermal acceptance tests will also be conducted to verify that the electrical power delivered from the APU at elevated temperatures meets the design requirements.

Concurrently with the thermal acceptance testing, the flight instrumentation will be checked for proper response.

4.2.3 Packaging Operations

After satisfactory completion of the acceptance tests the following packaging operations will be performed (Figure 24):

- a) The filler blocks and lock rods will be installed on the reflector.
- b) The reflector will be removed and the shipping sleeve installed. The flight drum drive system will be installed on the reflector and the assembly packaged for shipment to the launch facility.

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Figure 24. APU Shipping Containers

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- c) The thermal shield will be fitted to the APU to ensure proper fit, then packaged for shipment to the launch facility.
- d) The APU will be removed from the vacuum chamber, packaged in its container, and stored in the APU storage area.

4.3 PROCEDURE FORMAT

Each of the above procedures will be written with a standard format. If a particular section of the format does not apply for a given test or final assembly operation, the section will be included with a statement that the section does not apply. This format will be as follows:

- a) Title
- b) Objectives The objectives will state the expected condition of the APU or its subsystems at the completion of the procedure.
- c) Estimate of Time This will include the time required to complete the operation of any section of the test that would be unwise to interrupt at a shift change.
- d) Hazards The hazards of the test or final assembly operation and the methods used to preclude them will be stated.
- e) Precautions and Limitations This section will state the safe operating limits of the particular operation.
- f) Test or Final Assembly Operation Location The location in the facility that the test or final assembly operation will be conducted will be specified.
- g) Equipment Required The equipment required to do the job in a safe manner will be specified.
- h) Initial Conditions The initial condition of the APU and related systems before a test or final operation is initiated will be specified. This includes alarm settings on monitoring equipment.
- i) Condition that Must be Satisfied Before The conditions that must be satisfied before performing a particular step in a procedure will be specified as required.

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- j) Variables to be Manipulated APU parameters to be varied during the test or assembly operation will be specified.
- k) Variables to be Recorded The variables to be recorded during the test or assembly operation will be specified.
- l) Procedure The procedure section will give the step by step operation. The procedure will not provide operating instructions for the facility subsystems; these will be in the Facility Operations Manual.
- m) Test and Final Assembly Check-Off Sheet Each step in the procedure will be administrative controlled by the check-off sheet.

4.4 TEST PROCEDURES

Those test procedures concerned with reactor operations are described in this section. Detailed operating procedures will be presented in the operations manual.

4.4.1 Reactor Startup and Operation Procedure

Objectives To start up and operate the reactor during acceptance tests in a safe manner.

Estimate of Time

Precautions and Limitations

- a) The reactor shall be sealed in a coded vessel and shielding installed before reactor operation.
- b) Inverse count approaches to critical will always be used during reactor startup.
- c) Control circuitry permits the movement of only one drum at a time when adding reactivity, but permits the motion of all four drums simultaneously when removing reactivity.
- d) A minimum of two operations personnel will be in the control room during reactor operation.
- e) The reactor shall not be made critical on the least reactive portions of a drums. A 10-degree margin at each end of the reactive

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portion of each drum, i. e., 0 to 10° and 125° to 135°, shall be excluded from use as the final drum motion during reactor startup.

Hazards During reactor operation, the reactor is isolated by a containment vessel and shielded by concrete shield blocks. This isolation is designed for a maximum credible accident of a 40 Mw-sec excursion without overexposure to the operations personnel.

Location The reactor will be operated in the test vault in the ATF.

Equipment Required

- a) Nuclear instrumentation
- b) Nuclear control console
- c) Test drum drive kits

Initial Conditions

- a) Reactor sealed in the vacuum chamber using established procedures
- b) Shield blocks installed
- c) The source mounted at the core
- d) Drum drive kits installed, position indicators calibrated, scram capability demonstrated, and position reproducibility determined
- e) Hydraulic hoist at its lower limit switch
- f) Nuclear detectors positioned on stand.

Conditions That Must be Satisfied Before Reactor Startup

Startup Check Sheet A startup check sheet will be taken before each startup and signed off by the Shift Engineer. The following items will be included:

- a) Hydraulic hoist lower limit switch
- b) Vacuum vessel sealed
- c) Shield blocks in place
- d) Calibrate nuclear instrumentation
- e) Scram settings

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- f) Bypass keys in use
- g) Startup source visible on startup channels
- h) Alarm test
- i) Startup interlocks satisfied
- j) Scram times for drum No. 1 _____
Scram times for drum No. 2 _____
Scram times for drum No. 3 _____
Scram times for drum No. 4 _____
- k) All drums set at 135.0°.

Scrams The cause of any scram must be determined. If it is a scram caused by operating parameters exceeding limits posted in the control room and discussed in Section 5.3, the approvals required for restart must be obtained as specified in Table V, Section 5.3.

If the cause of the scram is caused by a spurious signal to an instrument, restart approval is required by the Shift Engineer.

If the cause of the scram is caused by an instrument malfunction, the restart must be delayed until the cause is corrected.

The Startup Check Sheet need only be taken on restarts if the reactor has been down over 4 hr.

Variables to be Manipulated The reactivity of the core will be changed by drum position and core temperature.

Variables to be Recorded During startup, the inverse count rate will be plotted as a function of core reactivity.

During reactor operation, the events which occur will be logged in the Operators Log Book.

Procedure The reactor will be made critical by inserting one drum at a time following these rules:

- a) With all drums in the least reactive position make a count measurement using one of the log count rate channels and the scaler.
- b) Insert drum No. 1 to its most reactive position and count for the same period as in step one.

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- c) Using the best reactivity and count measurement data, determine the corrected background count rate by the following formula:

$$B = \frac{\beta \rho_1 \rho_2 (C_1 - C_2) + \rho_2 C_2 - \rho_1 C_1}{\rho_2 - \rho_1} ,$$

where

B = background,

ρ_1 = reactivity of core in dollars with all drums in the least reactive position, (i.e. full out)

ρ_2 = reactivity of core in dollars with drum No. 1 inserted to its most reactive position, (i.e. full in)

C_1 = counts with all drums out,

C_2 = counts with drum No. 1 all the way in, and

β = delayed neutron fraction.

- d) Plot corrected initial count-to-current count ratio, c_0/c , as illustrated in Figure 25 after each reactivity addition
- e) Add reactivity in \$1.00 steps until the extrapolated corrected c_0/c ratio is 0.2 or larger
- f) Add reactivity in 40¢ steps until the extrapolated corrected count ratio is 0.1 or larger
- g) Add reactivity in 15¢ intervals
- h) After the last reactivity insertion the reactor will be on a sustained positive period limited to a minimum of 50 sec
- i) Allow the flux level to increase one decade above the level where the positive period was initiated. Level the flux at this point for 10 min and compare reactivity added to the core with the predicted value. If the reactivity falls outside of the limits given for the operation approval for continued operation is required as shown in Table V, Section 5.3.

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Figure 25. Reactor Startup Curve

Procedures for the manipulation of reactivity for various operations are to be specified in the procedures of those operations. A procedure check off sheet containing the following items will be completed.

<u>Procedure Check Off Sheet</u>	<u>Initials</u>	<u>Time/Date</u>
a) Reactor start or restart	_____	_____
b) Startup check sheet taken	_____	_____
c) If restart, restart conditions (following scram or normal shutdown)	_____	_____
d) Count data information (drum positions, counts, count ratio, and reactivity inserted)	_____	_____
e) Predicted reactivity inserted	_____	_____
f) Difference in actual and predicted reactivity inserted	_____	_____
g) Action Taken (Table V, Section 5.3)	_____	_____

4.4.2 Fuel Loading and Dry Critical Test Procedure

Objectives

- a) Load fuel-moderator elements
- b) Determine core nuclear parameters
- c) Perform operations in a safe manner.

Estimate of Time

Precautions and Limitations

- a) Only one person will be allowed to approach within 3 ft of the core after fuel moderator elements have been loaded. Additional personnel may be required in this area during operations not covered by this procedure, but they will remain outside the 3 ft distance.
- b) Two-way communication will be established between the reactor control room and test vault.

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- c) Reactor will be approximately 12 ft below floor level.
- d) A complete instrumentation checkout will be performed prior to dry critical test.
- e) Functional instrumentation check will be made no more than 4 hr before remote motion of the control drums.
- f) Source level will be visible on instrumentation during all loading steps.
- g) A minimum of two independent c_o/c curves will be plotted during loading operations. In all cases, the curve that predicts a criticality situation with the least number of fuel elements loaded will be used as the guide.
- h) Fuel elements will not be loaded to an extrapolated critical configuration with more than desired excess reactivity. If the c_o/c curve predicts this condition with the next element in the reactor, then elements loaded will be removed and the reactivity will be adjusted with low hydrogen content elements. These elements will be identified by numbers stamped on the end caps. A new c_o/c plot would be effected starting with this new core configuration.
- i) The fuel elements will be loaded in the order shown in Figure 26. The approach to critical is made by loading fuel from the center to the outside, replacing lucite dummy rods with fuel at each step. Thus the core is always reflected, and the reactivity increase per loading step is a minimum.
- j) One element at a time will be taken from the fuel vault and placed in the reactor. When fuel elements are removed from the reactor they will be returned to the vault in the reverse order in which they were loaded.
- k) Power to the drums will be locked off during fuel loading operation.

Hazards With established procedures, there are no undue hazards associated with this test. Experiments have been performed to determine the worth of fuel elements as a function of position in the core and to determine reactivity changes corresponding to reflector nominal thickness changes (Experiment SCA4C). When these results are available, a table of reactivity vs the

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Figure 26. 10FS Loading Sequence

number of fuel elements loaded for various nominal reflector thicknesses will be prepared. From these curves, a loading sequence will be determined.

Owing to variations in hydrogen content from one element to another, the critical loading may vary from one core to another. Therefore, criticality predictions will be determined by inverse multiplication plots for each core.

Test Location The reactor will be located in the test vault in the ATF approximately 12 ft below floor level as shown in Figure 27.

Equipment Required

- a) Nuclear instrumentation
- b) Nuclear control console
- c) Drum drive kits

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Figure 27. Fuel Loading

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- d) Work platform around reactor
- e) Drop deflector
- f) Core cap assembly mockup
- g) Lucite fuel elements
- h) Portable storage rack
- i) Count chamber mounting fixtures
- j) Grid plate handling tool
- k) Fuel element handling tool
- l) 5-curie neutron source with mounting fixture
- m) Fuel element holding fixture

Initial Conditions

- a) APU mounted in vacuum chamber
- b) Source mounted adjacent to the core opposite the chambers
- c) All instrumentation connections to control room made, checked out and instruments calibrated
- d) Drum drive kits installed and checked out
- e) Fuel loading sequence will be prepared for two complete sets of shims installed.

The proposed loading sequence, is based on achieving a critical configuration at 32 plus elements, with four drums in their most reactive position. The proposed schedule is shown below.

Fuel Loading Step	Number of Elements	Total
No. 1	13	13
No. 2	6	19
No. 3	3	22
No. 4	3	25
No. 5	3	28
No. 6	2	30
No. 7	1	31
No. 8	1	32
No. 9	1	33
No. 10	1	34
No. 11	1	35
No. 12	1	36
No. 13	1	37

- f) Control-drum-worth curves will be available to console operator
- g) Core loaded with dummy lucite elements
- h) Source mounted and visible on two count channels.

Initial Conditions That Must be Satisfied Before Remote Operation of Control Drums

- a) APU will be in the vacuum chamber with dome on. NOTE: After reactor is within two elements of extrapolated criticality with all four drums in the most reactive position, the dome will be sealed (see Item "g" - Precautions and Limitations).
- b) Hydraulic hoist will be at its lower limit switch.
- c) The concrete shield blocks will be placed over the test vault.
- d) The loading neutron source will be visible on the startup instrumentation.
- e) No interlocks will be bypassed during the operation unless specified in an approved step of the procedure.

Variables to be Manipulated

- a) Number and position and hydrogen content of fuel moderator elements in the core
- b) Position of control drums.

Variables to be Recorded

- a) The fuel element number, number of elements loaded and the position and hydrogen content of each element will be recorded at the completion of each loading step.
- b) The control drum positions
- c) Reactor flux will be recorded after each loading step with one, two, three, or four drums inserted. These data will be normalized and plotted to predict reactor criticality.
- d) Reactor period will be determined, recorded, and their associated excess reactivity after a critical configuration has been achieved.
- e) The reactor temperature will be recorded as a reference for reactivity determinations.

Fuel Loading Procedure

- a) Record source level on all nuclear channels with the following drum configurations:
 - 1) Control drum No. 1 in its most reactive position
 - 2) Control drums No. 1 and 2 in their most reactive positions
 - 3) Control drums No. 1, 2, and 3 in their most reactive positions
 - 4) Control drums No. 1, 2, 3, and 4 in their most reactive positions
- b) Disable all four control drum drives.
- c) Clear high bay of personnel except for fuel loader and the monitor.
- d) Establish control room communication.
- e) Remove vacuum chamber dome.
- f) Install loading platform and drop deflector.
- g) Remove upper core cap mockup assembly and place in its rack.
- h) Remove top grid plate and place in its rack.
- i) In accordance with the established loading sequence check the fuel elements out of the vault one at a time and load them in the core after removing the appropriate lucite dummy element.
- j) After all of the elements for any one loading step have been loaded, the number, identification and location of the fuel elements in the core will be verified utilizing the check sheet.
- k) Install the grid plate and core mockup assembly.
- l) Remove loading platform and drop deflector.
- m) Install vacuum chamber dome. Seal if within two elements of extrapolated criticality with all drums in their most reactive position.
- n) Install shield blocks.

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- o) Perform functional check of nuclear instrumentation if 4 hr have elapsed since their last check.
- p) Record output of all nuclear channels with:
 - 1) Control drum No. 1 in its most reactive position
 - 2) Control drums No. 1 and 2 in their most reactive positions
 - 3) Control drums No. 1, 2, and 3 in their most reactive positions
 - 4) Control drums No. 1, 2, 3, and 4 in their most reactive positions
- q) Drive all drums to their out limit switches.
- r) Disable control drums.
- s) Remove shield blocks.
- t) Repeat steps c through o until within one element of a critical configuration with control drums 1, 2, and 3 in their most reactive positions and control drum 4, in an intermediate position. At this time criticality will be approached following the reactor operation procedure.
- u) After reactor has been made critical determine excess reactivity after each loading step.
- v) Repeat steps c through u until all 37 elements have been loaded.

4.4.3 Reflector Installation and Removal Procedure

Objectives To install and remove the reflector in a safe manner.

Estimate of Time Set up fixture. Remove or install one half of reflector-
shipping sleeve.

Precautions and Limitations

- a) The control drums shall be locked in their least reactive position. The handling fixture holding the reflector halves uses the void filler blocks as pickup points.
- b) Never more than one half of the core shall be bare at one time. This will preclude the possibility of an infinite reflector on more than one side of the core.

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c) The reflector handling fixture shall prevent personnel from placing their whole body within 1 ft of the exposed side of the core.

d) Special keys for control of procedural sequence shall be employed.

Hazards A discussion of the shutdown margins during the reflector handling procedure for various reflector configurations that will exist is presented in Appendix A-2.

Mechanical interlocks and procedure check off sheets are in effect during the reflector handling procedure to ensure that only the above core-reflector-sleeve configurations will exist during the operation.

Test Location Over the test vault in the ATF.

Equipment Required

- a) Shipping sleeve
- b) Reflector installation fixture, indexing mechanism and support adapter
- c) Work platform
- d) APU drop deflector.

Initial Conditions

- a) Reflector installation Both halves of shipping sleeve mounted on the core. Void-filler blocks and locking devices holding drums in their least reactive position. The reflector handling fixture properly indexed to the APU.
- b) Reflector removal Both reflector halves mounted on the core. Void-filler blocks and locking devices holding drums in their least reactive positions. The reflector handling fixture properly indexed to the APU.

Conditions That Must be Satisfied Before Reflector Installation or Removal Void-filler blocks and locking devices holding drums in their least reactive position.

Variables to be Manipulated None.

Variables to be Recorded None.

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Procedure The procedure for installation of the reflector is presented in Figure 28.

4.4.4 Wet Critical and Nuclear Acceptance Test Procedure

Objectives Establish core reactivity conditions and make shim adjustments to ensure proper excess reactivity to enable the APU to complete its mission.

Estimate of Time

Precautions and Limitations of Test

- a) Reactor startup procedure to be used for all starts and restarts.
- b) Approximate drum worth curves will be available. This data shall be confirmed during core reactivity checks in the loading operation and the critical check prior to NaK loading.
- c) After critical, reactivity insertions are to be limited to \$0.20, as determined from the best worth curve estimates.
- d) Alarms, scrams, and setbacks (Table I)
 - 1) Alarm on high power
 - 2) Reactor scram on high power
 - 3) Vacuum valves close on high power
 - 4) Reactor scram short period
 - 5) Vacuum valves close on short period
 - 6) Reactor setback on short period
 - 7) Earthquake scram
 - 8) Alarm on instrument malfunction

Hazards Personnel hazards associated with this test are minimized because:

- a) Core reactivity has been previously demonstrated during fuel loading and the dry critical check after welding the core cap to the vessel.
- b) Reactor is contained in a coded vessel and shielded by concrete blocks.

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- 1 APU IN HANDLING FIXTURE (VERTICAL). HANDLING FIXTURE CAP REMOVED
- 2 SHIPPING SLEEVE (CORE VESSEL PROTECTION SHIELD) IN PLACE
- 3 FOUR REFLECTOR EJECTION SPRING COMPRESSING TOOLS IN PLACE WITH SPRINGS COMPRESSED
- 4 FOUR REACTOR VESSEL LOWER HINGE PINS REMOVED
- 5 REFLECTOR INSTALLATION FIXTURE (TRACKS & DOLLIES) ATTACHED TO UPPER SURFACE OF HANDLING FIXTURE
- 6 REFLECTOR ASSEMBLIES INSTALLED ON DOLLIES (TURRETS ROTATED SO THAT REFLECTOR ASSEMBLIES FACE AWAY FROM REACTOR)
- 7 ROTATE CRANK TO DRIVE DOLLY (A) INTO POSITION TO ATTACH DOLLY TO SHIPPING SLEEVE BY MEANS OF ATTACH POINTS REPEAT FOR DOLLY (B)
- 8 REMOVE SHIPPING SLEEVE RETAINER (SLEEVE HALVES NOW HELD IN POSITION BY DOLLIES (A) & (B).)
- 9 ROTATE CRANK DRIVING DOLLY (A) AWAY FROM THE REACTOR TO THE END OF TRAVEL
- 10 UNLOCK DOLLY TURRET (A), ROTATE 180° & LOCK INTO POSITION SO THAT REFLECTOR ASSEMBLY NOW FACES THE REACTOR (SHIPPING SLEEVE HALF MAY NOW BE REMOVED FROM DOLLY, IF DESIRED)
- 11 ROTATE CRANK TO DRIVE DOLLY (A) TOWARDS REACTOR ASSEMBLY TO A POSITION CLOSE TO THE REACTOR ADJUST POSITION OF REFLECTOR BY MEANS OF ADJUSTMENTS ON DOLLY SO THAT THE REFLECTOR HINGE HALVES ALIGN WITH THE REACTOR VESSEL SUPPORT HINGE HALVES
- 12 ROTATE CRANK TO DRIVE DOLLY (A) TOWARDS THE REACTOR UNTIL THE LOWER HINGE PIN HOLES ARE IN LINE INSTALL THE LOWER HINGE PINS & SAFETY
- 13 REPEAT STEPS 9 THROUGH 12 USING CRANK ON DOLLY (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 DOLLY ATTACHING SCREWS FROM VOID FILLER ASSEMBLIES ON THE REFLECTOR ASSEMBLIES ROTATE CRANKS TO MOVE DOLLIES (A) & (B) AWAY FROM THE REFLECTOR ASSEMBLIES
- 17 REFLECTOR ASSEMBLIES ARE REMOVED & SHIPPING SLEEVES INSTALLED USING THE ABOVE PROCEDURE BY SUBSTITUTING "REFLECTOR ASSEMBLY" IN PLACE OF "SHIPPING SLEEVE" & VICE VERSA THROUGHOUT THE PROCEDURE

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Figure 28. Reflector Installation

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- c) The control drums shall be locked in the least reactive position before shim adjustments are made on the reflector.
- d) Operation is controlled by check off sheets and procedures.

Test Location The operation will be performed in the test vault in the ATF.

Equipment Required

- a) Nuclear control instrumentation
- b) Nuclear control console
- c) Drum drive kits

Initial Conditions

- a) Reactor loaded with fuel and NaK
- b) NaK heaters installed
- c) All low temperature instrumentation, and equipment removed

Initial Conditions That Must be Satisfied Before Remote Operation of the Control Drums All reactor starts and restarts will be governed by the reactor operation procedure.

Variables to be Manipulated

- a) The control drums shall be moved to various configurations during drum calibrations measurements.
- b) The reactor flux will be ramped during period measurements.
- c) The reactor temperature shall be elevated to determine temperature coefficients of reactivity.

Variables to be Recorded

- a) The control drum positions
- b) Reactor flux
- c) Reactor temperature

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Procedure

- a) Start up the reactor using the established startup. The predicted critical position will be based on experimental NaK worth data and the critical check performed after the core cap welding operation.
- b) The control drum worths will be determined by period techniques and the excess reactivity will be determined.
- c) The excess reactivity will be adjusted with reflector shim plates at room temperature.
- d) The NaK temperature will be increased to the operating level and the excess reactivity measured. If it does not meet the design criteria, the reflector will be adjusted and the test repeated.

4.4.5 Reactor Shim Adjustment Procedure

Objectives Adjust the reflector shims to provide the excess reactivity required to meet the operational requirements for the APU during its intended life cycle.

Estimate of Time This test will run concurrently with the dry and wet critical nuclear acceptance tests.

Precautions and Limitations

- a) Reactor startup and operation procedure to be used for all reactor starts, restarts and operation
- b) Only one person will be allowed to approach within 3 ft of the core.
- c) Power to the drums will be off and drums locked out during shim adjustments. Nuclear instrumentation will remain on.

Hazards Using the established procedure, there are no undue hazards associated with this test.

Prior to any shim adjustment, the excess reactivity of the core will be known. Experiments are being conducted that will give total core reactivity and the worth of the fine control drums as a function of shim configuration. With this data available, the total reactivity of the core is predictable for each shim adjustment. This will allow the Shift Engineer to plan an orderly sequence of shim adjustments to give the proper reactivities.

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A Health and Safety monitor will determine the radiation level and specify the working time at the reactor before personnel will be allowed to initiate any adjustment procedure. Operator dose will be limited on all operations as specified in AI Standard Operating Procedures and the AEC Manual.

Shim adjustments will be made after the excess reactivity has been determined. Previous experimental data, following similar tests on other SNAP 10A critical assemblies, has yielded dose rates of 400 mr/hr at the surface and 50 mr/hr at one foot from the reactor after a cooling period of less than 15 minutes. A minimum waiting period of one hour is required to remove the shield blocks and vacuum chamber dome before access to the reactor is available. Therefore, excessive radiation levels are not anticipated.

Location The reactor will be located in the test vault in the ATF approximately 12 ft below floor level as shown in Figure 27.

Equipment Required

- a) Same as for reactor operation
- b) Shim plate rack

Initial Conditions

- a) Cold excess reactivity known from either dry or wet critical tests
- b) Shim adjustment sequence available

Initial Conditions That Must be Satisfied Before Remote Operation of Control Drums All reactor starts and restarts will be governed by the reactor startup and operation procedure.

Initial Conditions That Must be Satisfied Before Adjusting the Reflector Shims

- a) Drum power off at console. Nuclear instrumentation on.
- b) Drums locked out

Variables to be Manipulated Shim configuration will be changed to give proper excess reactivity.

Variables to be Recorded

- a) Shim configuration

- b) Excess reactivity
- c) Average core temperature

Procedure

- a) Prepare the shim adjustment sequences from the experimental data to provide the proper cold excess reactivity
- b) Disable control drums
- c) Open vault, remove vacuum chamber top, and install work platform around the reactor
- d) Establish communication with control room
- e) Lock control drums in out position
- f) Make required shim adjustments
- g) Remove work platform and prepare for reactor startup
- h) Repeat steps a through g until the desired shim configuration has been achieved.

4.5 PROCEDURE REVIEW

4.5.1 Procedure Modification

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

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

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The Procedure Review Form will be filled out by a member of the operations unit who is familiar with the operational problems and will be approved by people who are responsible for the safety of the operation.

In the first section, the present method shall be described. This description will not be a step-by-step account but the general method proposed to do a specific operation.

The second section will present the proposed change in method.

The third section will present the reasons for the proposed change. Where applicable, the appropriate sections in the Safeguards Report will be referenced to indicate that the changes are within its limitations.

The fourth section will present the new procedure. The section that the procedure change is in shall be presented in its entirety.

The fifth section will have the new check sheet for the revised section.

The sixth section will provide space for the necessary reviews and approvals as specified in Reference 6.

4.6 TEST REQUEST

It is anticipated that, during the acceptance testing program, additional testing may be required. The operations to be performed during these tests will be controlled by standard procedures. In the event that the test will significantly affect the reactor operating limits, the approval will come from the AEC. All special tests will be initiated by the Acceptance Test Unit in the following manner.

- a) The procedure will be written in the standard format previously described.
- b) The Test Request Form is filled out and attached to the procedure.
- c) The Test Request Form and procedure will then be submitted for the necessary reviews and approvals (Reference 6). The format is presented below.

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PROCEDURE REVIEW FORM

Procedure Title _____

1. Present Method
2. Proposed Change(s)
3. Reasons for Change(s)
4. New Procedure
5. New Check Off Sheet
6. Approvals: (See Reference 6)

REACTOR TEST PROCEDURE

Approvals:
(see Reference 6)

Test No.:
Date:
Prepared By:

Contents

I. Objective of Test	Page _____
II. Description of Test	Page _____
III. Expected Results	Page _____
IV. Procedures	Page _____
V. Results and Conclusions	Page _____

4.7 APU MODIFICATIONS

During acceptance testing and final assembly operations, modifications to the APU may become necessary. All proposed modifications not affecting safety will be submitted to AI Project for approval and will be performed in the ATF. Administrative control over these operations will be effected by detailed procedures.

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5. OPERATION

5.1 GENERAL

A report (NAA-SR-7422) has been issued which defines the standards for controls, procedures, and approvals involving nuclear facilities under the jurisdiction of the Compact Systems Division (Reference 6). Included in these standards are the following:

- a) Organizational responsibilities and authorities
- b) The recording and approval of reactor operating activities
- c) The definition of abnormal reactor conditions and their consequent restrictions on reactor operation
- d) The training, qualification and approval of supervisory and operator personnel
- e) The development, approval and updating of summary hazards reports
- f) The development, approval and maintenance of facility and reactor operations manuals
- g) The development and approval of special reactor test procedures.

5.2 OPERATIONS RECORDS

In addition to the reports required in NAA-SR-7422, the ATF will require the following records.

Facility Check Sheet A bi-hourly check sheet will be maintained to ensure that the plant is in a safe operating condition. These data will be kept in the Facility Check Sheet Book which will be located in the Shift Engineer's office.

Test or Final Assembly Check Sheet Each acceptance test or final assembly operation will be detailed in a step by step procedure. A Test or Final Assembly Check Sheet will be an integral part of these procedures. This check sheet is divided into four parts. The first is the test initiation section, the second is the completed step sign off section, the third is the data recording section, and the fourth is the procedure completion sign off section.

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

The completed step sign off section ensures that individual procedural steps are satisfactorily completed before new steps are initiated.

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

The procedure-completion section documents the satisfactory completion of the test or operation and that the system is ready for the next acceptance test or final assembly operation.

Nuclear Startup Check Sheet A Nuclear Startup Check Sheet will be filled out within 4 hr before reactor startup. The check sheet will also be used on restarts following a scram or normal shutdown if the reactor has been down for 4 hr. These check sheets will be kept in a Startup Check Sheet Book in the Shift Engineer's office.

Recorder and Data Logger Records Recorder and Data Logger Records shall be changed daily and stored in individual envelopes for each day. The daily envelopes shall be stored separately for each APU.

Scram Log Book All reactor or heater scrams caused either by abnormal operating conditions or by spurious signals shall be recorded in a Scram Log Book that will be kept at the console.

Facility Check Sheet Book The Facility Check Sheet Book will house the daily Facility Check Sheets and will be kept in the Shift Engineer's office.

Nuclear Startup Check Sheet Book The Startup Check Sheets used during reactor operation shall be housed in the Nuclear Startup Check Sheet Book which shall be stored in the Shift Engineer's office.

Test and Final Assembly Log The Test or Final Assembly Check Sheets that are used for any one APU will be put into a Test and Final Assembly Log. The purpose of this book is to document the satisfactory completion of the final assembly and acceptance test operations.

Instrumentation Maintenance Log The facility instrumentation will be serviced on a routine basis. These maintenance records will be kept in an

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Instrumentation Maintenance Log which shall be kept in the Shift Engineer's office.

5.3 ABNORMAL REACTOR CONDITIONS

The Operations Manual will contain a table which categorizes pertinent parameters and sets values for normal and graduated levels of abnormal conditions. Appropriate approved entries are listed in Table V, showing the actions and levels of approval required to continue or resume operation after detection of an abnormal condition.

TABLE V
ABNORMAL OPERATING CONDITIONS

	Normal Operations	Operation Supervisor Approval to Continue	Group Leader ⁽⁵⁾ Approval to Continue Program
Period (sec) ⁽¹⁾	∞ to 15	15 to 10	< 10
Power level (% normal) ⁽²⁾	0 to 110	110 to 120	> 120
Maximum (non-nuclear) NaK temperature (°F)	70 to 1050	1050 to 1150	> 1150
Unaccountable reactivity changes (\$)			
a) During continual operation of a given reactor	< 0.05	0.05 to 0.10	> 0.10
b) Following reassembly or replacement of reflector or other components or between different reactors	< 0.15	0.15 to 0.25	> 0.25
Vacuum system vent ⁽³⁾ monitor radiation level (times background)	1 to 3	3 to 5	> 5
Facility (high bay) radiation level during reactor operation (mr/hr)	0 to 5	5 to 15	> 15

(1) Period setback at 15 sec, scram at 10 sec

(2) Nuclear power level scram at 120% normal (normal $\cong$ 16 watts)

(3) Vacuum system valves close automatically at 2 times background

(4) RAS initiates siren at 20 mr/hr

(5) See Section 5.3

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In the event the values of parameters shown in Column 2 of Table V are reached or exceeded, the Operations Supervisor shall be notified and his approval obtained to restart the reactor if a scram has occurred. Those abnormal conditions which do not initiate a scram will require the following action: (a) The abnormal condition will be corrected without shutting down the reactor. (b) The Supervisor will be notified immediately and approval obtained to continue reactor operations or shutdown.

In the event the values of parameters shown in Column 3 of this table are reached or exceeded, the test program will be stopped and the Group Leader shall be notified and his approval obtained before continuing the test program. All operations in excess of the parameters listed in Column 3 shall be reported in writing by the Group Leader to the Manager and Associate Manager of the Compact Systems Division, to the Director and Associate Director of the Department involved, and to the Chairman, Compact Reactors Committee, Reactor Safeguard Review Panel, within 48 hr. If, after evaluation, the Group Leader considers that plant damage may have occurred, the reactor will remain shutdown until conditions have been reviewed with the Compact Reactors Committee, their recommendation obtained, and specific written approval has been received from the Approval Authority for restart.

5.4 ATF OPERATIONS PERSONNEL

The operating staff of the Acceptance Test Facility will consist of several categories of personnel as outlined below:

- a) During each APU acceptance test program, the facility will be operated on a shift basis with 24-hr coverage. The minimum crew for each shift will consist of the following personnel:

- 1 Shift Engineer or Shift Supervisor
- 1 Chief Operator or Associate
- 2 Reactor Operators or Mechanics

These personnel will be responsible for final assembly, nuclear and nonnuclear testing data reporting, and operation of auxiliary systems required for the test program. In addition, launch operations personnel will be available to assist ATF personnel as part of the on-the-job training program for this group.

- b) Relief personnel required for vacations, illness, etc., will be drawn from the analysis group listed in (d) on the following page.

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- c) One instrument technician and one mechanic will be responsible for the preventive and emergency maintenance that will be required. They will assist day shift personnel as required.
- d) Three engineers will be responsible for the day-to-day analysis and evaluation of the data obtained from APU tests. They will maintain close contact with SNAP 2 and 10 engineering groups, so that all experimental results will be made available to the units responsible for future design.
- e) The supervisor will be responsible for the overall coordination, scheduling and control of the testing program and will provide personnel to carry out the above assignments.

5.5 OPERATING PHILOSOPHY

5.5.1 General

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

5.5.2 Safety Standards

The safety standards for the facility shall be set in accordance with the standard operating policies by the Health and Safety Section and as they apply to standard operations covered in the manual. All plant rules and regulations shall be in effect at all times. Emergency and safe handling of hazardous materials procedures are covered in manuals published by the groups that are responsible for the use of these materials.

5.6 OPERATING RULES

In addition to the Basic Operating Rules presented in NAA-SR-7422,⁶ the following rules will apply to the operation of the ATF.

Control Room The number of persons in the control room shall be limited at the discretion of the Shift Engineer. During operation of the reactor

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the number of persons in the control room will be limited to a total of ten. Of these, there will be a limit of five nonduty personnel or visitors. During APU shutdown periods when the control system is connected, at least one person will be continuously on duty in the control room.

High Bay Access Access to the high bay is restricted at all times. Entry is controlled by the Shift Engineer.

Entry Behind Instrument Racks During the conductance of a test, permission for entry behind the instrument racks is required from the Shift Engineer.

Use of Bypass Switches Bypass switches are key operated and these keys shall be in the possession of the Shift Engineer who is responsible for the use of these keys. In general, bypass switches are for satisfying interlocks for checkout purposes only.

Console Key The console key shall be in the possession of the Shift Engineer when not in use on the nuclear console. The Shift Engineer is responsible for its use.

Reflector Drum Control Keys The reflector control keys that unlock the locking devices on the control drums shall be in the possession of the Shift Engineer. These keys will be used only during the performance of a test or operation that is covered by an approved procedure and controlled by its check sheet.

Operating Limits The operating limits for the acceptance tests are specified in the individual procedures. That these limits are in effect is documented by the Shift Engineer in the Test Checkoff Sheet.

Hydraulic Hoist After fuel loading has been initiated, the hydraulic hoist (with APU installed) will never be raised above the lower limit without the void filler blocks installed and the drums locked out. No movement of the reactor ever occurs in the ATF unless the reflector is in this condition or has been replaced with the shipping sleeve.

5.7 EMERGENCY PROCEDURES

5.7.1 Responsibility for Action

AI Industrial Security is responsible for coordination of the overall Radiological Emergency Plan for Santa Susana.¹ Current master evacuation

routes and emergency assembly areas are shown in Figure 29. Emergency action outside of the ATF area is under the direction of AI Industrial Security. In the event that hazardous materials are involved in the emergency, concurrence of the Health and Safety Department is required prior to re-entry into the facility.

Emergency action within the ATF area is under the direction of the Shift Supervisor. Communications, emergency units, and medical assistance necessary for coping with emergencies within the ATF will be provided by AI Industrial Security upon request from the Shift Supervisor.

5.7.2 Classification of Emergency

The following paragraphs define and indicate area responsibilities for the various classifications of emergencies in order of severity. It is recognized that, in the final analysis, classification of an emergency must depend on the judgement of the Shift Supervisor.

- a) Class I Emergency An emergency of a localized nature; control of the situation can be handled by personnel assigned to the facility with possible backup assistance from established emergency units. The Shift Supervisor remains in control of the facility.
- b) Class II Emergency An emergency of such magnitude and extent as to require evacuation of the area involved and pose an imminent threat to other facilities in the immediate area; control of the situation requires active assistance from established emergency units. AI Industrial Security assumes control of the facility after the shift personnel evacuate. The Shift Supervisor maintains control of the shift personnel after evacuation.
- c) Class III Emergency An emergency of such magnitude and extent that other facilities are definitely affected and major emergency procedures are involved; control of the situation requires full activation of established emergency units. AI Industrial Security assumes control of the facility after shift personnel evacuate. The Shift Supervisor maintains control of the shift personnel after evacuation.

Figure 29. Evacuation Route and Emergency Assembly Area

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5.7.3 Action to be Taken

5.7.3.1 Class I Emergency

a) Shift Engineer

- 1) Order reactor scrammed, if necessary.
- 2) Notify AI Industrial Security Control Center at Santa Susana of the situation, via the "RED" telephone line or other provided means, saying, "This is Building 019. We have a Class I emergency at Building 019, repeat, we have a Class I emergency at Building 019."
- 3) Order all unnecessary personnel from area.
- 4) Equip personnel with necessary protective equipment.
- 5) Take direct action as necessary to meet the emergency.
- 6) Continuously assess situation, to determine if the class of the emergency should be changed.

b) Chief Operator

- 1) Inform ATF Unit Supervisor of the emergency.
- 2) If hazardous materials are involved, call Health and Safety representative.
- 3) Monitor radiation levels if possible, and inform Shift Supervisor of findings. Continue this duty until the arrival of the Health and Safety Department representative.
- 4) Assist in meeting the emergency.

c) Console Operator

- 1) Scram the reactor, if so ordered by Shift Supervisor.
- 2) Assist in meeting the emergency.

d) All Other Operations Personnel

- 1) Assist in meeting the emergency.

5.7.3.2 Class II and Class III Emergencies

a) Shift Engineer

- 1) Order reactor scrammed.
- 2) Order evacuation of the area to emergency assembly area No. 4 (EAA No. 4).

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- 3) Notify AI Industrial Security Control Center at Santa Susana of the situation.
 - 4) Evacuate to EAA No. 4.
 - 5) Ascertain that all personnel have reported to EAA No. 4.
- b) Chief Operator
- 1) Direct other personnel to the emergency assembly area.
 - 2) Evacuate to EAA No. 4.
- c) Console Operator
- 1) Scram reactor and activate emergency button.
 - 2) Obtain a portable survey meter, if readily available.
 - 3) Evacuate to EAA No. 4 with Console Log Book.
- d) All Other Operations Personnel
- 1) Obtain a portable survey meter, if readily available.
 - 2) Evacuate to EAA No. 4.

5.7.3.3 Radiological Alarm Siren Sounds

- a) Shift Engineer
- 1) Order reactor scrammed.
 - 2) Order all personnel to evacuate to EAA No. 4.
 - 3) Immediately evacuate to EAA No. 4.
- b) Console Operator
- 1) Scram reactor.
 - 2) Immediately evacuate to EAA No. 4 with Console Log Book.
- c) All Other Operations Personnel
- 1) Immediately evacuate to EAA No. 4.

5.7.4 Practice Evacuation

Practice evacuation will be participated in by ATF personnel at least two times a year. The ATF Unit Supervisor will ensure that ATF personnel participate in sufficient practice evacuations that they are familiar with evacuation procedures. This may require scheduling of practice evacuations in addition to those normally scheduled by AI Industrial Security.

During reactor operation, any personnel over and above the minimum operating crew will participate in the practice evacuation; reactor operation, however, will not be discontinued. Personnel participating in practice evacuations will assemble at EAA No. 4.

6. SAFEGUARDS CONSIDERATIONS

6.1 GENERAL

The most serious potential hazard associated with the operation of a nuclear reactor is the release of its fission product inventory. This inventory results from long-term operation of the reactor at power and/or the accidental occurrence of a power excursion. Since this facility will be used only for zero-power test, any significant fission product inventory will arise only from an accidental power excursion.

The consequences of a fission product release from a power excursion are generally much less severe than from an extended power run. The buildup of long-lived fission products is prevented, owing to the extremely short time interval of the excursion.

The basic containment barriers are the fuel cladding, core vessel and closed-loop primary system, and reactor containment vessel (vacuum vessel). In addition, some local containment is provided by the underground vault (in which the vacuum vessel is located) and the reactor building.

Non-nuclear accidents are associated primarily with the release of toxic materials into the atmosphere. The occurrence of a NaK fire in the vicinity of the core would be the prime cause of such release.

The consequences of these potential accidents are discussed in this section.

6.1.1 NaK Experience

Atomics International experience in handling NaK as a reactor coolant began in the fall of 1959 when the SER (SNAP Experimental Reactor) was first filled with coolant. Since that time there have been no serious NaK accidents. In those few instances where NaK fires have occurred, they have been either quickly extinguished or intentionally allowed to burn out.

6.1.2 SNAP 2 Experience

The SNAP 10 reactor is similar in design to reactors which have been developed by, or are presently being operated by Atomics International for the Atomic Energy Commission. The SER has been tested extensively and its nuclear

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characteristics determined. After 6000 hr at critical, the SER was disassembled and replaced by the SNAP Developmental Reactor (S2DR). The S2DR has completed a 21-month test program during which it was operated for 48 days at 1200°F. These two reactors, along with the original critical experiments, have provided a wealth of experimental information regarding the nuclear characteristics of these systems.

6.1.3. Low-Power Operation

This facility is designed for nuclear and thermal acceptance testing of the SNAP 10 reactors prior to shipment. Therefore, only zero-power tests will be performed. Zero-power tests are defined here as tests in which the power level is up to four orders of magnitude above source critical. With a neutron source emitting 10^7 n/sec (5 curies Pu-Be) and with the reactor core initially \$5.22 subcritical, the reactor power would not exceed 16 watts.

6.1.3.1 Area Radiation Levels

During the zero-power tests, the shield blocks of the vault will be in place. These blocks are composed of 4 ft of ordinary concrete. The dose rate directly over these blocks at a power level of 16 watts (the maximum value during these tests) would be 2.5 mrem/hr (1.8 mrem/hr from gamma-rays and 0.7 mrem/hr from neutrons). These values are based on one neutron leaking out of the core per fission of which about 35% have energies greater than 0.4 Mev. The gamma-ray dose rate was calculated on the basis of 14 Mev total photon energy emitted per fission and an average energy per photon of 3.0 Mev.

With the shield blocks in place, an annulus of 1/4 in. exists through which streaming can occur. A dose rate of 7.5 mrem/hr has been calculated for personnel standing over this annulus when the reactor is at 16 watts.

6.2 NON-NUCLEAR CONSIDERATIONS

The occurrence of a NaK fire after the APU is filled is credible, though the probability is small. If a NaK leak occurs, it will probably drip down through the APU and burn on the instrument compartment or at the bottom of the vacuum vessel — many feet from the reactor core. However, the occurrence of a NaK fire in the vicinity of the core was examined and is discussed in this section.

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6.2.1 Hazardous Materials

The hazardous materials which will be considered in this section are:

- a) Beryllium
- b) Uranium
- c) Radioactive fission products.

The presence of NaK is not to be considered as potentially dangerous as the above mentioned materials. Though it may burn and become airborne as caustic fumes, it is easily detected long before the concentration reaches maximum permissible limits.

6.2.1.1 Controls

In case of NaK fire, the high bay area will provide some but not total containment of any toxic materials. The building ventilation system will be shut down to inhibit the spread of these materials to adjacent areas. Except for the vacuum cooling system, there will be complete exclusion of all water and aqueous solutions from the high bay area. Provisions will be made in the handling and storage of the NaK coolant to minimize the occurrence of accidental spills and subsequent fires.

6.2.2 Maximum Credible Non-Nuclear Accident

6.2.2.1 Nature of Accident

The accident considered is a major NaK leak in the vicinity of the core and subsequent ignition.

6.2.2.2 Consequences Considered

6.2.2.2.1 Beryllium Air Concentration

It has been shown experimentally at Atomics International that the maximum temperature for sodium fire is about 1650°F (900°C). It will be assumed that the temperature of the NaK fire is the same. Figure 30 represents experimental data on the equilibrium Be vapor concentration as a function of Be metal temperature.⁷ Assume further, conservatively, that the temperature of the Be during a NaK fire reaches 900°C and that the concentration in the vault and high bay area reaches the equilibrium value shown in Figure 30. On this basis, the

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Figure 30. Beryllium Air Concentrations

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concentration would be 2.7 micro-gm/m^3 compared to an MPC value of 2.0 micro-gm/m^3 . Considering the degree of conservatism, no problem is anticipated from the vaporization of Be. However, the oxidation of Be and the subsequent release of BeO into the atmosphere presents an additional problem. Experiments performed at Atomics International⁸ indicate that the oxidation of Be is relatively slow during the first 2 hr at temperatures up to 2000°F , and that the oxidation follows the parabolic rate law. Specifically, at 1650°F there are 0.06 milli-gm of oxygen consumed per cm^2 of Be during the first 2 hr of oxidation in air. Let us now assume that it takes 30 min to extinguish a NaK fire in the vicinity of the core. This is a realistic estimate based on experience with extinguishing Na and NaK fires. The 0.06 milli-gm of O_2 per cm^2 of Be is reduced to 0.03 for the 30-min oxidation period. With a Be surface area of approximately 2600 cm^2 , it may be calculated simply that 44 milli-gm of Be are oxidized. If all this Be were to become airborne and distribute itself homogeneously throughout the high bay area, the concentration would be about 12 micro-gm/m^3 . This concentration is greater than the MPC for continuous exposure; it is, however, allowable for short periods of time, 30 min or less (Reference 13). In addition, fire fighting personnel will routinely don respiratory protection for any fire involving hazardous materials.

6.2.2.2.2 Fission Product Air Concentration

The normal fission product inventory was calculated using the CURIE DOSE IBM Code developed by Atomics International.¹⁵ The fission product inventory shown below, Table VI, is that following one hour of normal, zero-power (16 watt) operation, i.e., 16 watt-hr.

TABLE VI
NORMAL FISSION PRODUCT INVENTORY

Cooling Time	Total Activity (curies)	Volatile Activity (curies)	* Effective I^{131} (curies)
0	40	9.1	1.4×10^{-2}
10 sec	34	6.9	1.4×10^{-2}
100 sec	23	3.6	1.4×10^{-2}
1000 sec	10	1.4	1.4×10^{-2}
1 hour	4	0.88	1.4×10^{-2}

*Effective I^{131} is equal to that amount of I^{131} necessary to give the same dose to the thyroid as the sum of the significant iodines.

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Under the most adverse conditions it would be possible for the Hastelloy-N fuel cladding to reach the temperature of the NaK fire, i.e., 1650°F. At this temperature the cladding ruptures at an internal hydrogen pressure of 1000 psi. This hydrogen pressure is reached when the fuel temperature reaches 1525°F (based on a hydrogen concentration of 6.5×10^{22} atoms/cc). It is possible, therefore, for the fuel elements to rupture. The hazards associated with the rupturing of fuel elements come from the volatilization of uranium and the release of any fission product activity generated during the zero-power tests.

Assuming that all the volatile (including iodine) activity immediately after a zero-power test is released into the high bay — a total high bay volume of 3600 m^3 — the initial dose rates due to submersion in fission gases and inhalation of iodine are 0.2 r/hr and 3.7 rem per hour of exposure, respectively. Assuming that leakage from the building is negligible, the total maximum exposure to personnel in a 30-min period is 0.014 rem (whole body) from volatiles and 1.8 rem thyroid dose. These exposures were determined using the basic techniques presented in Reference 9 and 11 with the data in Table VI.

6.2.2.2.3 Uranium Air Concentration

The specific activity of uranium is 65 micro-c/gm. This is based on 326 millicuries of U^{234} and U^{235} in a total of 5 kgm of fuel. Assume that the partial pressure of uranium in the room (as calculated using Dalton's law) is equal to the vapor pressure of the uranium. At 1650°F (the temperature of the NaK fire) the vapor pressure is about 10^{-10} mm Hg. The specific activity of the uranium in the air may be calculated simply to be 6.5×10^{-14} micro-c/cc. The MPC for uranium in the air is 5×10^{-11} micro-c/cc. It should be stated that this analysis is predicated on two reasonable assumptions.

- a) That a cladding rupture does not constitute a complete loss of cladding around the fuel
- b) That due to the continuous release of hydrogen at 1000 psi through the fissure or crack in the cladding there will be no inleakage of oxygen (14.7 psia) and therefore no direct oxidation of uranium into UO_2 with release of particulates

Leakage of hydrogen from the APU will most probably occur in the tubing or through the expansion compensators as these are estimated to be the weakest points in the system.

The activation of NaK can be neglected since at a power level of 16 watts for 1 hr the specific activity of NaK is 10^{-2} microcuries per gram.

6.2.2.3 Emergency Action

In the event of a NaK fire within the facility, the building ventilation system will be shut off manually. This will be done in an attempt to control the fire and reduce the spread of any hazardous airborne materials. Heat detectors in the building will actuate local alarms at the Industrial Security Control Center. All operations personnel will be well trained in combating NaK and electrical fires. In the event that a NaK fire encompasses any portion of the reactor and/or the beryllium reflector, protective clothing, including respiratory protection, will be used by all fire-fighting personnel.

6.2.2.4 Preventive Measures

Prior to loading the APU with NaK, all welds in the APU will be radiographed and the entire system flushed with an inert gas. The actual loading of the coolant into the APU will be performed in strict accordance with NaK handling procedures. Proper fire-fighting equipment will be on hand at all times.

6.2.2.5 Conclusions

As may be noted from the above discussion, none of the accidents postulated present any serious hazards to personnel. For beryllium, the maximum air concentration in the high bay area is approximately six times the maximum permissible concentration. However, personnel will evacuate the building immediately and all fire-fighting personnel will use respiratory protection. The release of the volatile fission products into the high bay area will result in a personnel exposure (in 30 min) within the facility of 0.014 rem whole body and 1.8 rem thyroid. This value is an acceptable exposure for any emergency condition.

6.3 NUCLEAR CONSIDERATIONS

6.3.1 General

There are two factors which will contribute to the safe operations of the ATF. As stated earlier in this section of the report, only zero-power acceptance tests will be performed in this facility. During these tests, scram capability will be available on each of the four reflector drums. This capability

allows the reactor to be brought more than \$5.00 subcritical within a time interval of 0.3 sec. Stringent administrative controls will ensure that, during the zero-power tests, the reactor will be brought to no more than four orders of magnitude above source critical, that is, about 16 watts.

In addition, the loss of hydrogen from the core, caused by fuel-rod rupturing, will remove reactivity from the core and cause it to shut down irreversibly following an excursion.

A survey of the operations conducted with the fueled APU was performed to determine the maximum credible accident. A description of these operations, along with postulated accidents and safeguards, is presented in Appendix A.

6.3.2 Nuclear Excursion

It will be shown in following paragraphs that the maximum energy released in the event of a nuclear excursion is 40 Mws. The core fission-product inventory from this excursion is given in Table VII.

6.4 MAXIMUM CREDIBLE ACCIDENT

6.4.1 Assumptions

The maximum credible nuclear accident will be based on a 40-Mws nuclear excursion during dry critical. It is further conservatively assumed that no containment whatever is provided by either the vacuum chamber or the vault. Two cases are then considered:

- a) No containment in the high bay area for calculations of downwind dose
- b) Total containment in the high bay for calculations of dose received by personnel within the ATF.

The excursion fission product inventory was calculated using the statistical formula:¹

$$Q = 1.8 \times 10^6 P t^{-1.2},$$

where P = Mws with "t" in seconds.

While the formula is reasonably accurate for times greater than 10 sec, the curie inventory, and hence the dose received, during the initial 10 sec following

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the excursion is overestimated. In view of the low values obtained, this degree of conservatism was retained.

Volatile activity is assumed to be 20% of the total fission products. Effective I^{131} remains essentially constant at 0.25 curies/Mws for the initial period of interest and up to 12 hr after the excursion.

The consequences of a nuclear accident during wet critical are less severe than the maximum credible accident stated above, for two reasons. One, the magnitude of the nuclear excursion for a comparable ramp insertion is 10 Mws¹⁰ instead of the 40 Mws given above. Second, the vacuum chamber will be evacuated, rather than air filled at atmospheric pressure as in the case of dry critical.

6.4.1.1 Maximum Energy Release

A nuclear accident is defined here as one in which the reactor power undergoes a positive period until the subsequent temperature rise is sufficient to rupture the fuel element cladding. The accident is assumed to occur from the continuous insertion of one control drum as a result of operator failure and failure of all scram circuitry. The maximum energy released as a result of this accident was determined as follows. The maximum rate at which each drum can be rotated in is 0.5°/sec. This results in an average rate of reactivity insertion over the entire 100° of movement of the drum which will produce a power excursion of 40 Mws.¹⁰ An excursion of this magnitude will raise the average fuel temperature to 1900°F and release 17.5% of the hydrogen. This is considered to be the maximum credible accident and is used as a basis for the discussion in the following sections.

A simultaneous rotation in of all four drums at their maximum speed was also considered. Reactivity would be added at a rate which would produce a 50-Mws excursion. However, this situation is not considered credible with the control system involved, since the circuitry will allow only one drum at a time to be driven in.

6.4.1.2 Postulated Hydrogen Release

The temperature of the fuel-moderator, making the conservative assumption of no heat loss, is 1900°F, following a 40-Mws power excursion.

This temperature is sufficiently high to cause cladding rupture and hydrogen release. Hydrogen continues to be evolved, though at a decreasing rate as the temperature of the rod decreases, due to the dissociation energy (43 kcal/gm-mole H_2) of hydrogen. The temperature decreases 30°F for each 1% loss of hydrogen. The release of 17.5% of the total hydrogen is sufficient to reduce the fuel-moderator temperature to 1400°F and irreversibly shut down the reactor.

6.4.1.3 Fission-Product Release Model

The fission-product release model which best fits this particular nuclear accident is presented in this section. Experimental work is underway to determine the extent of fission-product release for SNAP 10A reactor fuel under various conditions. This information will be utilized fully in future reports as it becomes available. The release model chosen here is that presented in the AI Reactor Facilities Evaluation Report.¹ In essence, it is assumed that the release of volatile fission products is controlled primarily by diffusion, and that the release fraction is inversely proportional to the square root of the molecular weight of the diffusing species. As shown above, the fraction of hydrogen released from the fuel during a maximum credible accident is 17.5% (64 ft³ at STP).

The average molecular weight of the volatile fission products is approximately 100, varying between the 80's for Kr and 130's for Xe and I. Since the molecular weight of hydrogen is two, the volatile fission product release is equal to $\sqrt{2/100}$ or about 1/7 of the hydrogen release. The releases are summarized below:

	<u>% Release</u>	<u>Curies Released At Time Zero</u>
Volatile release	2.5	3.6×10^5
Effective iodine	2.5	0.25
Other fission products	Negligible	Negligible

The above activity is distributed uniformly throughout the high bay area (about 3600 m³). It is assumed (Case a) that no credit is taken for the integrity of the facility, and 50% of the iodines are deposited on the walls of the facility. The 3600 cubic meter volume is now postulated to drift downwind as a single cloud having an initial specific activity of 100 microcuries/cc of rare gas activity (decaying as $t^{-1.2}$) and 34×10^{-6} microcuries/cc of iodine activity.

6.4.1.4 Consequences of Maximum Credible Accident

Table VII indicates the downwind thyroid dose (from iodine inhalation) and the total body external cloud gamma dose under strong inversion conditions following a 40-Mws excursion.

TABLE VII
CONSEQUENCES OF MAXIMUM CREDIBLE ACCIDENT

	Allowable ¹	Nearest On-Site Building	Nearest Site Boundary	Nearest Community
Distance, ft	-	60	250	15,000
Thyroid dose, rem	300	1.8	1.7	Negligible
Whole body cloud gamma dose, rem	25	1.6	0.27	Negligible
Ground deposition dose, rem (iodine)	1.7	3.2×10^{-3}	3.2×10^{-3}	Negligible

Since the maximum credible accident takes no credit for the integrity of the facility, all calculations were based on a ground release. To obtain the total integrated exposure (TIE) from a ground release, Holland's formula¹² was used with the exponent, $h = 0$. Thus, we may write

$$TIE = \frac{2Q(t)}{\pi C^2 \bar{u} (x_o + d)^{2-n}} \text{ curie-sec/m}^3,$$

where $Q(t)$ is the released activity reaching the point, d , at time, t , corrected for decay at time, t ; $\bar{u}$ is the average wind velocity; C and n are meteorological parameters. For on-site determinations of TIE under conditions of strong inversion and ground release, the following meteorological conditions and parameters were chosen:¹

$$C = 0.04$$

$$n = 0.5$$

$$\bar{u} = 0.5 \text{ m/sec.}$$

The value, x_o , is the upwind, virtual point source distance in meters. The virtual point source distance is given by the following equation:

$$x_o = \left(\frac{V}{\pi^{3/2} C^3} \right) \frac{2}{3(2-n)} \text{ Meters,}$$

where V is the initial cloud volume in cubic meters; the remaining terms have already been defined. It should be noted that Holland's virtual point source concept was originally developed for puff-type releases of which the accident release chosen here is a prime example. Under these conditions, the volume V is merely the dilution volume of the high bay area; i.e., about 3600 m³. The virtual point source distance may be simply calculated to be 1300 meters. A better physical significance of this distance may be realized by understanding that if Q_o curies (the activity released at time zero as shown in the preceding section) were released at ground level as a point source 1300 meters upwind, the radioactive cloud would have a volume V at the site location.

The total integrated exposure within the high bay area, assuming total containment (Case b), is calculated as follows. Assume the fission product cloud is distributed throughout the high bay volume and is decaying at the rate, t^{-1.2}, where t is in seconds. Again, even though an immediate evacuation is required, the integrated exposure to personnel within the facility will be determined for a 30-min residence time.

The total cloud dose for a 30-min exposure is 8.1 rem. This was determined using the inventory values from the formula, page 105, the calculational techniques presented in Reference 9, and the release model discussed in paragraph 6.4.1.3.

As noted previously there will be 0.25 curies of I¹³¹ (effective) released into the building at the time of the incident. The iodine concentration within the facility is, therefore, 6.95 x 10⁻⁵ μc/cc. Since 1 μc per cc of iodine corresponds to 515 rem integrated dose to the thyroid per sec of exposure time, personnel within the building would receive, in a 30-min period, a thyroid dose of:

$$D = 515 \times 6.95 \times 10^{-5} \times 1800 = 64 \text{ rem.}$$

This is less than the 300 rem allowable thyroid dose for an accident.

The lung dose was determined as follows. At time zero, the volatile fission product activity would be 100 μc/cc. This corresponds to 3.7 x 10⁶ d/sec-cc. Since the lung dose is due primarily to the beta particles, and, since

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we can assign an average beta energy of 0.3 Mev, the beta activity in the building (again at time zero) is 1.1×10^6 Mev/cc-sec. The air volume in the lung is approximately 10^3 cm³; and the lung mass is approximately 10^3 gms; therefore, the beta energy deposited per gram of lung is 1.1×10^6 Mev/sec. This corresponds to a lung dose of 1.8×10^{-2} R/sec. With the activity decaying as $t^{-1.2}$ we get an integrated lung dose for a 30-min period of 0.07 rem; an insignificant value.

6.4.2 Emergency Action

In the event of a nuclear excursion, the following emergency actions will be taken:

- a) The ventilation system for the facility will be manually shut off.
- b) Radiation detectors located in the high bay area will measure the severity of the incident as far as operating personnel are concerned. If any of these detectors read in excess of a preset value, they will actuate local alarms and alarms at the Industrial Security Control Center.
- c) Evacuation to established areas will be instituted as required.

6.4.3 Conclusions

An examination of Table VII indicates that the consequences of the maximum credible accident are well below the acceptable whole-body exposure of 25 rem at the nearest site facility and site boundary, and negligible at the nearest community. The direct dose at these locations due to prompt neutrons and gamma rays would be negligible, since the reactor is assumed to be in the vault (some 10 ft underground) at the time of the excursion. Within the facility itself, for a 30-min exposure, the total integrated whole body dose is 8.1 rem in the high bay area, a thyroid dose of 64 rem, and a lung dose of 0.07 rem. The direct exposure, immediately over the 4-ft-thick concrete plug, is 1.7 rem, owing to prompt neutrons and gamma rays. These values are again within the maximum acceptable limits of an emergency exposure.

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APPENDIX A
NUCLEAR SAFETY DURING OPERATIONS
PERFORMED WITH FUELED APU

This section presents a review of the operations to be performed with the fueled APU, with a hazards analysis of each operation. These studies are included as supplementary information to the discussions of maximum credible accidents.

Reactivity values presented in this section are based on unpublished data from the SCA-4-C and SCA-4-B experiments. All values are considered to be on the conservative side.

A-1 DRY CRITICAL

Objectives Load reactor with a combination of fuel moderator elements with nominal hydrogen densities of 6.5×10^{22} and 6.0×10^{22} atoms/cm³ to provide an excess reactivity of \$3.00 (in the vault) with two shims on all reflector surfaces arranged for shimming. This is a nominal setting that will provide adequate flexibility for making final adjustments during nuclear acceptance tests.

The following reactivities will result at the completion of the core loading.

a) Excess reactivity (75°F core temperature) with:

1) Four drums in	\$+2.75
2) Three drums in	+0.67
3) Two drums in	-1.41
4) One drum in	-3.49
5) No drums in	-5.57
6) No drums in plus void filler blocks	-4.55

b) Worth of each drum +2.08

c) Worth of single human standing adjacent to
reactor with no void filler blocks in place +0.35

d) Worth of single human standing adjacent to
reactor with void filler blocks in place +0.30

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Initial Conditions

- a) APU mounted in vacuum chamber
- b) All instrumentation connections to control room made, checked and instruments calibrated
- c) Drum drive kits installed and checked out
- d) Control drum worth curves will be available to console operator
- e) Core loaded with dummy lucite elements
- f) Source mounted and visible on count channels
- g) Fuel loading sequence prepared

The proposed loading sequence is based on achieving a critical configuration at 32 plus elements with four drums in the most reactive position. The proposed schedule is shown below.

<u>Fuel Loading Step (No.)</u>	<u>Number of Elements</u>	<u>Total</u>
1	13	13
2	6	19
3	3	22
4	3	25
5	3	28
6	2	30
7	1	31
8	1	32
9	1	33
10	1	34
11	1	35
12	1	36
13	1	37

Initial Conditions That Must be Satisfied Before Remote Operation of Control Drums

- a) The APU in the vacuum chamber with the dome on. NOTE: After the reactor is within two elements of extrapolated criticality with all four drums in the most reactive position, the dome will be sealed.

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- b) Hydraulic hoist at lower limit switch.
- c) The concrete shield blocks in place over the test vault.
- d) The loading neutron source visible on the startup instrumentation
- e) No interlocks bypassed during the operation unless specified in an approved step of the procedure

Reactor Status During Operation (For procedure see Section 4.4.2)

- a) The reactor loaded with lucite elements and reflector shimmed with two shim plates on all surfaces that can be shimmed. No reactivity associated with the core.
- b) Reactor loaded with fuel elements while replacing the dummy lucite elements from the center outward
- c) After the reactor has a critical configuration, control drum worths will be determined to establish the excess reactivity subsequent to each element loading. In the event that the predicted excess reactivity exceeds \$3.00, enough high-hydrogen-content elements (6.5×10^{22} atoms/cm³) will be replaced by low-hydrogen-content fuel elements (6.0×10^{22} atoms/cm³) to reduce the extrapolated excess reactivity to \$3.00.
- d) During the fuel loading steps, the shutdown margin will be greater than \$4.30. The worth of a man next to the fully loaded core with no filler blocks installed has been estimated to be \$0.35. The differential worth of the last five elements loaded with respect to the lucite elements has been measured and found to be \$0.52 per element. Therefore, after a fuel element has been loaded, the maximum change in reactivity during the remaining loading steps is \$0.35 for the man and \$0.52 for the element, giving a total of \$0.87. After the last element has been loaded, the shutdown margin is \$5.60 less \$0.35 for the man standing by or \$5.25.

Postulated Accident During fuel loading, the minimum shutdown margin was shown to be \$5.25. This means that an accident could only be caused from the addition of reactivity by the inward motions of control elements. For purposes of analysis the maximum accident is as follows:

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Initial Conditions

- a) Reactor in the pit approximately 12 ft below floor level
- b) Shield blocks off of the pit
- c) Vacuum vessel dome off
- d) Reactor fully fueled
- e) Total excess reactivity available is \$3.00.

Accident One control drum is turned in at its maximum rate of rotation of $0.5^\circ/\text{sec}$. This corresponds to a reactivity insertion rate of $1.5\text{¢}/\text{sec}$. (For details see Section 6.4.)

Consequences A nuclear excursion causing a 40 Mws energy release. The average fuel element temperature reaches 1900°F , thus rupturing the cladding, releasing 17.5% of the hydrogen, and 2.5% of the rare gas and iodine fission products. The total integrated exposure to personnel within the high bay is less than 8.1 rem. Downwind exposures at the nearest site facility and at the site boundary do not exceed 2 rem. Negligible exposures occur at the nearest community. (For details see Section 6.4.)

Safeguards Against Postulated Accident Before the shield blocks are removed, the power to the drum drive clutches will be locked off, using the console key. This will be controlled administratively by the use of a checkoff sheet.

The power and logic necessary to make the drum motors move in either direction are limited in the in position to a single drum. This is illustrated in Figure 8 and accomplished by Switch 206.

The drum motion is powered by stepper motors. These machines can rotate only when the coils are energized in the proper order and with the proper overlap. Any mode of failure, in the motor or in the control circuitry, to give continuous electrical power to the drum motors will result in only one step of drum motion that could be in either direction. This step is 0.225° of drum rotation.

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A-2 REFLECTOR INSTALLATION AND REMOVAL

Objectives Install or remove reflector on fully loaded reactor.

Initial Conditions

- a) Reflector Installation Both halves of shipping sleeve mounted on the core. Void-filler blocks and locking devices holding drums in their least reactive position.
- b) Reflector Removal Both reflector halves mounted on the core. Void filler blocks and locking devices holding drums in their least reactive position.
- c) Operation takes place on the hoist at floor level.

Conditions That Must be Satisfied Before Reflector Installation or Removal Void filler blocks and locking devices holding drums in their least reactive position.

Reactor Status During Operation (For procedure see Section 4.4.3)

NOTE: Reactivities given in this section are for reactor adjusted for flight conditions. These are tabulated in Section 3.6.3.

Reflector Installation

- a) With shipping sleeve on both sides of the core, the shutdown margin is \$18.00.
- b) Install reflector installation fixture. During this step, the worth of a man is estimated to be \$0.30. Therefore, minimum shutdown margin is \$17.70.
- c) Remove one half of sleeve with one side of the core bare. The shutdown margin is \$19.10. The maximum worth of a man next to the bare side of the core is estimated to be \$7.00. Therefore, the minimum shutdown margin is \$19.10 less \$7.00 or \$12.10, with one man next to bare side.
- d) Install reflector half plus void filler on the bare side of the core. The shutdown margin is \$11.30. The maximum worth of a man is estimated to be \$0.30. Therefore, the minimum shutdown margin is \$11.30 less \$0.30 or \$11.00.

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- e) Remove other half of shipping sleeve, leaving one half of the reactor bare. The shutdown margin is \$12.40. The maximum worth of one man next to the bare side of the core is estimated to be \$7.00. Therefore, the minimum shutdown margin is \$5.40.
- f) Install other reflector half plus void filler on the bare side of the core. The shutdown margin is \$4.60. The maximum worth of a man next to the fully reflected core with void fillers installed is estimated to be \$0.30. This gives a minimum shutdown margin of \$4.60 less \$0.30 or \$4.30.

Reflector Removal

- a) Reflector on both sides of reactor with void fillers installed. The shutdown margin is \$4.60.
- b) Install reflector installation fixture. During this step, the worth of a man is estimated to be \$0.30. The minimum shutdown margin is \$4.60 less \$0.30 or \$4.30.
- c) Remove one half of the reflector with one side of the core bare. The shutdown margin is \$12.40. The maximum worth of a man is estimated to be \$7.00. Minimum shutdown margin is \$12.40 less \$7.00 or \$5.40.
- d) Install shipping sleeve on the bare side of the core. The shutdown margin is \$11.30. The maximum worth of a man is \$0.30. The minimum shutdown margin is \$11.30 less \$0.30 or \$11.00.
- e) Remove reflector half leaving other side of the core bare. The shutdown margin is \$19.10. The maximum worth of a man next to the bare core is estimated to be \$7.00. The minimum shutdown margin is \$19.10 less \$7.00 or \$12.10 with one man next to the core.
- f) Install other half of shipping sleeve. The shutdown margin is \$18.00. The worth of a man next to the core under these conditions is estimated to be \$0.30. The minimum shutdown margin is \$18.00 less \$0.30 or \$17.70.

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Postulated Accident During reflector installation, the reflector installation fixture breaks when the core is half bare and the reflector on the other half. The installation fixture is removed for repair and, prior to replacing the shipping sleeve, one of the operating personnel walks up to the bare side as closely as possible.

Consequences As shown above, the reactivity changes from -12.40 to -5.40 . Since the core is still subcritical, $k_{\text{eff}} = 0.96$, there are no personnel hazards.

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

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

A-3 WELD CORE CAP AND UPPER HEADER ASSEMBLY

Objectives Weld core cap and upper header assembly on fully fueled reactor.

Initial Conditions

- a) Reactor with weld sleeve on both sides of the core. The weld sleeve will be 3 in. shorter than the regular shipping sleeve, to permit installation of the core cap welding fixture. This sleeve is similar to the regular one in the vicinity of active core region. The shutdown margin with the weld sleeve will be slightly greater than with a full sleeve and is estimated to be the same when the weld fixture is installed.
- b) Reactor at floor level above test pit with appropriate work platforms in place.

Reactor Status During Operation A weld sleeve will be on the reactor. This sleeve will permit operation of the core cap installation fixture. Under

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these conditions, the reactor shutdown margin will be at least \$15.50. During the welding process, the maximum worth of a man is estimated to be \$2.90. This gives a minimum shutdown margin of \$12.60 during this operation.

Postulated Accident No credible nuclear accident is postulated to occur during this operation.

Consequences None.

Safeguards The reactor is surrounded by protective equipment — weld sleeve and installation fixture. A minimum shutdown margin of \$12.60 exists during the operation.

A-4 NaK LOADING

Objective

- a) Fill the fully fueled APU reactor and associated piping system and hot flush with NaK.
- b) Seal NaK fill lines.

Initial Conditions

- a) Reactor sealed in the vacuum chamber in an inert atmosphere
- b) NaK fill lines hooked up to APU through ports in the vacuum chamber
- c) Shipping sleeve on both sides of the reactor
- d) Bottom of vacuum chamber at floor level

Reactor Status During This Operation

- a) The reactor shipping sleeve is on the reactor, providing a shutdown margin of \$18.00 prior to NaK loading.
- b) The worth of the NaK in the core has been calculated to be less than 1¢. Therefore, the shutdown margin is virtually unchanged.
- c) After the NaK flush, the vacuum chamber will be opened and the NaK lines sealed off. During this operation, the maximum worth of a man will be \$0.30, leaving a minimum shutdown margin of \$17.70.

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Postulated Accident As shown in the reactor status, the minimum shut-down margin is \$17.70, so no nuclear accidents are postulated. During the fill and flush operation the reactor is sealed in the vacuum chamber and is either in a vacuum or an inert atmosphere. If a NaK leak started, no fire would occur. After the fill and flush operation is completed, the chamber is slowly filled with air. Any NaK present in the chamber as a result of a leak will be slowly oxidized and no fire would occur.

During the NaK tube sealing operation a NaK leak could occur. In this case, the NaK would drip into drip pans and burn. This burning does not occur in the vicinity of the fuel elements and no fission products will be released.

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

Safeguards Drip pans and shield covers will be provided to protect the APU in the event of a NaK leak during the filling and sealing operations. Dry calcium carbonate will be placed in the drip pans and loading personnel will wear the required protective clothing.

A-5 WET CRITICAL AND NUCLEAR ACCEPTANCE TESTS

Objective The reactor shim configuration will be adjusted to provide the excess reactivity required to ensure successful completion of the APU's mission.

To maintain the nominal power output for one year, the initial excess reactivity required in space at 943°F (average core temperature) is \$0.40. To operate at this temperature in the ATF test vault requires an initial excess reactivity of \$0.76. The difference of \$0.36 is due to the test vault worth of +\$0.05 and subtraction of the power defect (no nuclear heat) hydrogen redistribution, and xenon of -\$0.41. During operation of the APU in the vault at an average core temperature of 75°F, the reactor will have an excess reactivity of \$2.75; that is, \$0.76 plus \$1.99 from the temperature defect.

The following reactivity values (from Section 3.6.4) for three sets of shims on the reflector, indicate that the required excess reactivity is available for operation in the ATF.

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Core Average Temperature (°F)	Drum Configuration (drums in)	Available Reactivity (\$)	Required Reactivity (\$)
943	4	+1.62	+0.76
75	4	+3.54	+2.67
75	3	+1.35	
75	2	-0.84	
75	1	-3.03	
75	No	-5.22	

Initial Conditions

- a) APU filled with NaK and the fill lines sealed
- b) Reflector installed and drum drives checked out
- c) Two shims on all reflector surfaces arranged for shimming

Reactor Conditions During Wet Critical and Nuclear Acceptance Tests (For procedures see Section 4.4.4)

- a) The initial approach to wet critical will be with the reflector shimmed with two complete sets of shims. The worth of the NaK is so small (\$0.0037) that the dry critical reactivity table (Section A-1) applies.
- b) After the wet excess reactivity has been determined, the reflector shims will be adjusted to give the reactivities given in the table in the objectives. At the time of the shim adjustments, the shutdown margin will vary from \$5.32 to \$5.57, and the worth of each drum will vary from \$2.08 to \$1.98. The maximum worth of a man adjacent to the core is \$0.35 (without void filler blocks) during this operation, making the minimum shutdown margin \$4.97.
- c) After the reactivity has been adjusted cold, the temperature of the core will be raised to 943°F average core temperature with electrical heat. The excess reactivity will be measured at this temperature and will be compared with the required excess of \$0.76. This operation is repeated until the hot excess reactivity meets the requirements.

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- d) After the reactor has been adjusted to the proper reactivities, the void fillers will be installed. The shutdown margin is then reduced to \$4.55. The worth of a man is decreased to \$0.30, making the minimum shutdown margin \$4.25.

Postulated Accident Same postulated accident as stated in Section A-1.

Consequences The result of a continuous ramp insertion with a cold, clean, wet core is an energy release slightly less than 40 Mws (Reference 10). If the core is hot, the excess reactivity is reduced and the energy release is reduced to 10 Mws. The consequences of these excursions are less severe than the 40 Mws excursion described in Section 6.4.

Safeguards The safeguards which apply to this operation are those described in Section A-1.

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