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SERIES A

REACTOR HEAT SOURCE DATA NASA BIDDERS CONFERENCE FOR SNAP 8 POWER CONVERSION

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REACTOR HEAT SOURCE DATA NASA BIDDERS CONFERENCE FOR SNAP 8 POWER CONVERSION

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Jerry Keyes
Authorizing Official
Date: 1-28-09

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DEPARTMENT OF ENERGY DECLASSIFICATION REVIEW	
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AUTHORITY: ADD	4. COORDINATE WITH:
NAME: Ted Davis	(5.) CLASSIFICATION CANCELED
	6. CLASSIFIED INFO BRACKETED
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ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.
P.O. BOX 309 CANOGA PARK, CALIFORNIA

CONTRACT: AT(11-1)-GEN-8
ISSUED: August 14, 1959

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TABLES

FIGURES

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INTRODUCTION

At the request of the AEC, AI has prepared and transmitted the following material to NASA for the SNAP 8 Bidders Conference.

I. REACTOR DESCRIPTION

A. SNAP 2 DEVELOPMENT INFORMATION

Since SNAP 8 is merely an extrapolation of the 3 kwe SNAP 2 system to higher power output, the following information is presented as background for the SNAP 8 system. SNAP 2 is a nuclear powered, mercury-Rankine power source being developed by the Missiles Projects Branch of the AEC for utilization in WS-117L, the Air Force reconnaissance satellite system. Atomics International is prime contractor to the AEC for the development of the auxiliary power unit.

B. AUXILIARY POWER UNIT

The SNAP 2 system consists of a reactor, shield, boiler, combined rotating unit, condenser-radiator, support structure, and automatic control system, as shown in Figure 1.

The reactor shown in Figure 2 consists of homogenous fuel-moderator, in the form of clad rods arranged in a close-packed triangular array forming (in cross section) a hexagonal core. A liquid metal coolant flows between the individual rods from a bottom entrance plenum to the exit plenum. The core assembly is contained in a stainless steel core vessel which in turn is surrounded by a beryllium reflector. Reactor control is effected by rotation of control drums located in the reflector. Safety action is obtained by separating the core and reflector in the radial direction. A numerical resume of the reactor characteristics is presented in Table I.

The combined rotating unit is shown in Figure 3. All dynamic elements (sodium pump, turbine, alternator, mercury pump, and bearings) are located on one 40,000 rpm shaft in a hermetically sealed housing. The sodium pump consists of a rotating permanent magnet which produces pumping action in a hermetically sealed axial sodium pumping section. The turbine consists of two axial flow impulse stages utilizing 100% admission. The alternator is a single phase, mercury cooled, synchronous machine using a canned permanent magnet rotor. Mercury lubricated bearings are used.

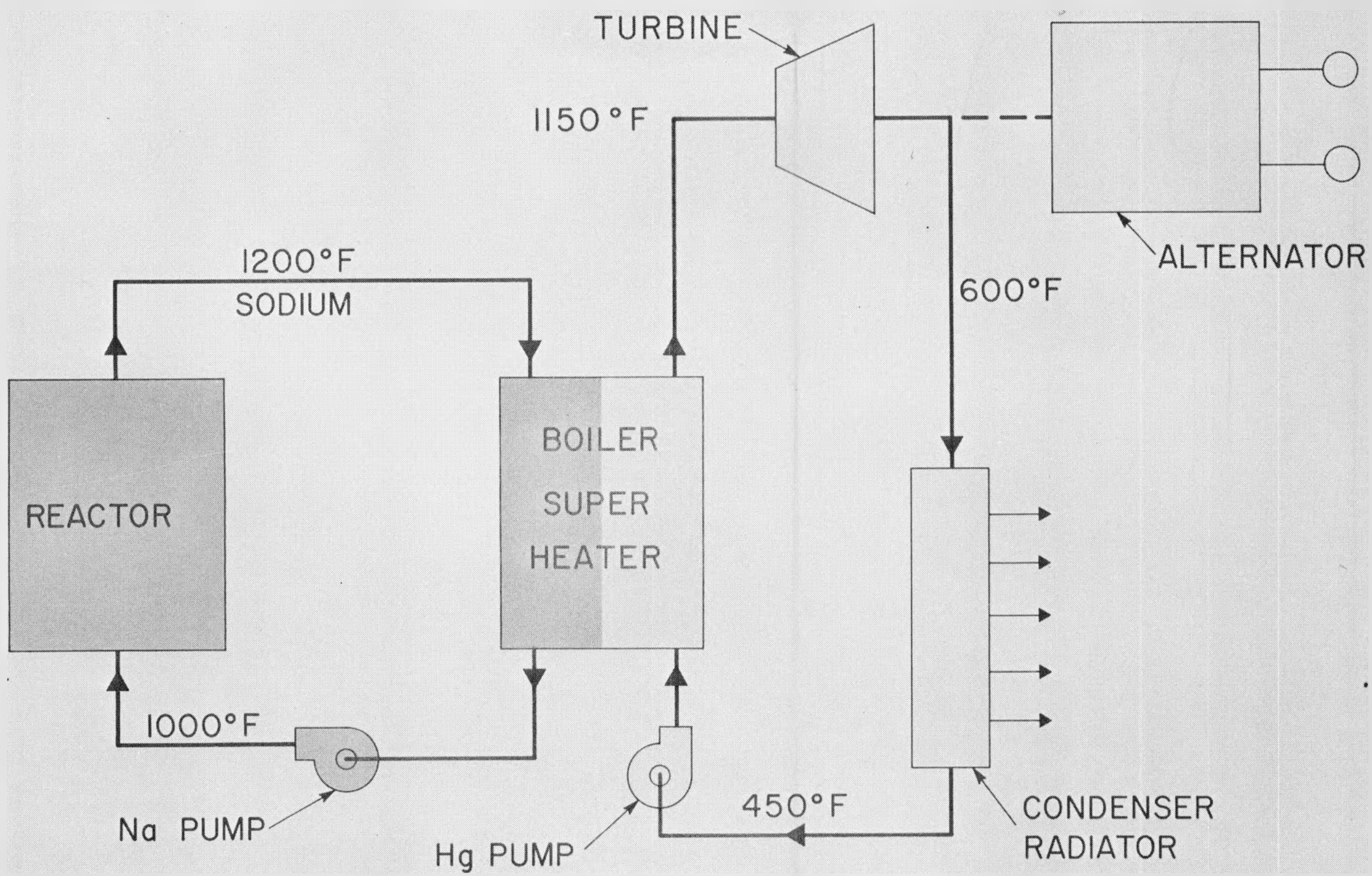

Figure 1. SNAP 2 Flow Schematic

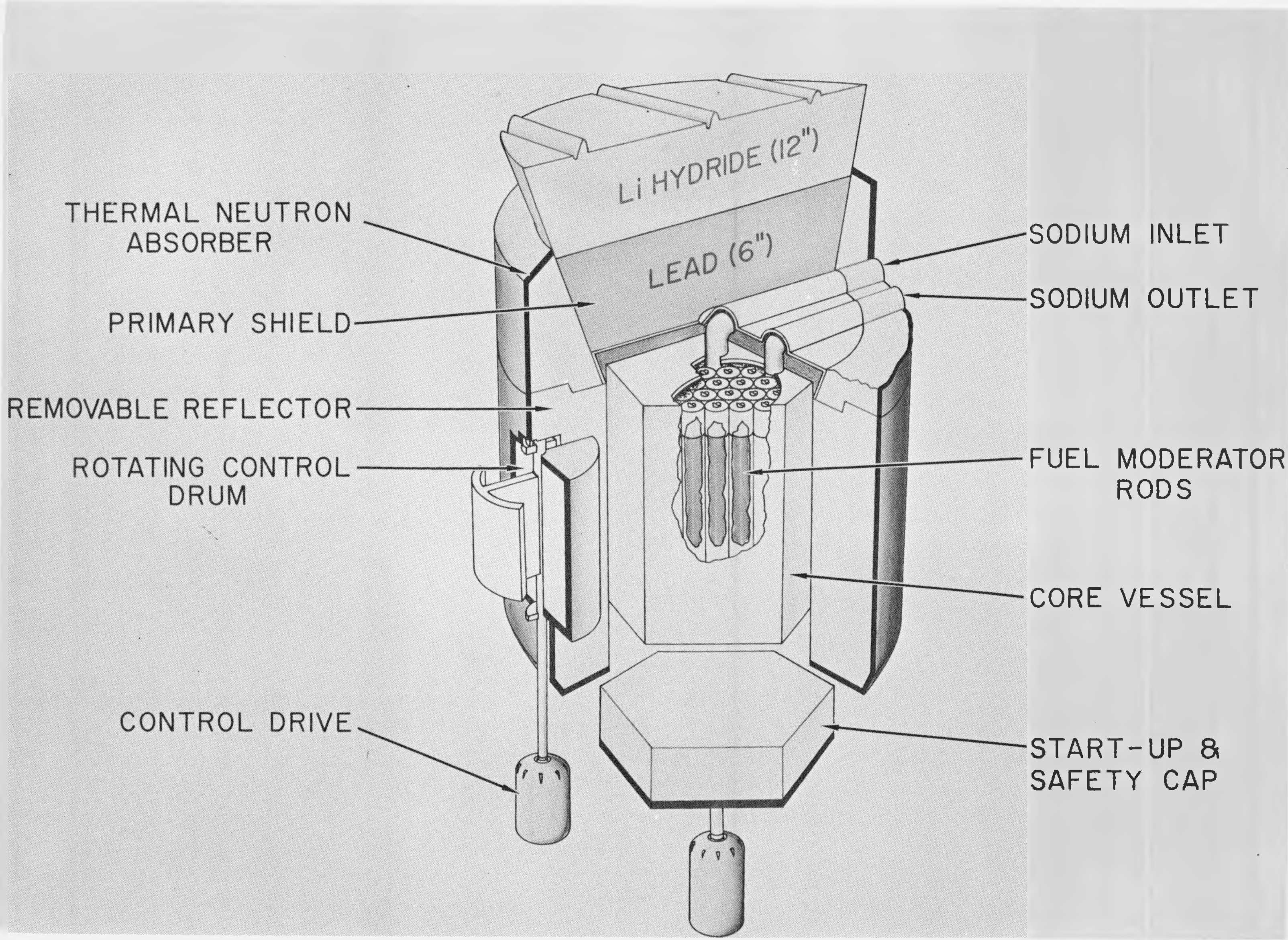

Figure 2. SNAP 2 Reactor Perspective

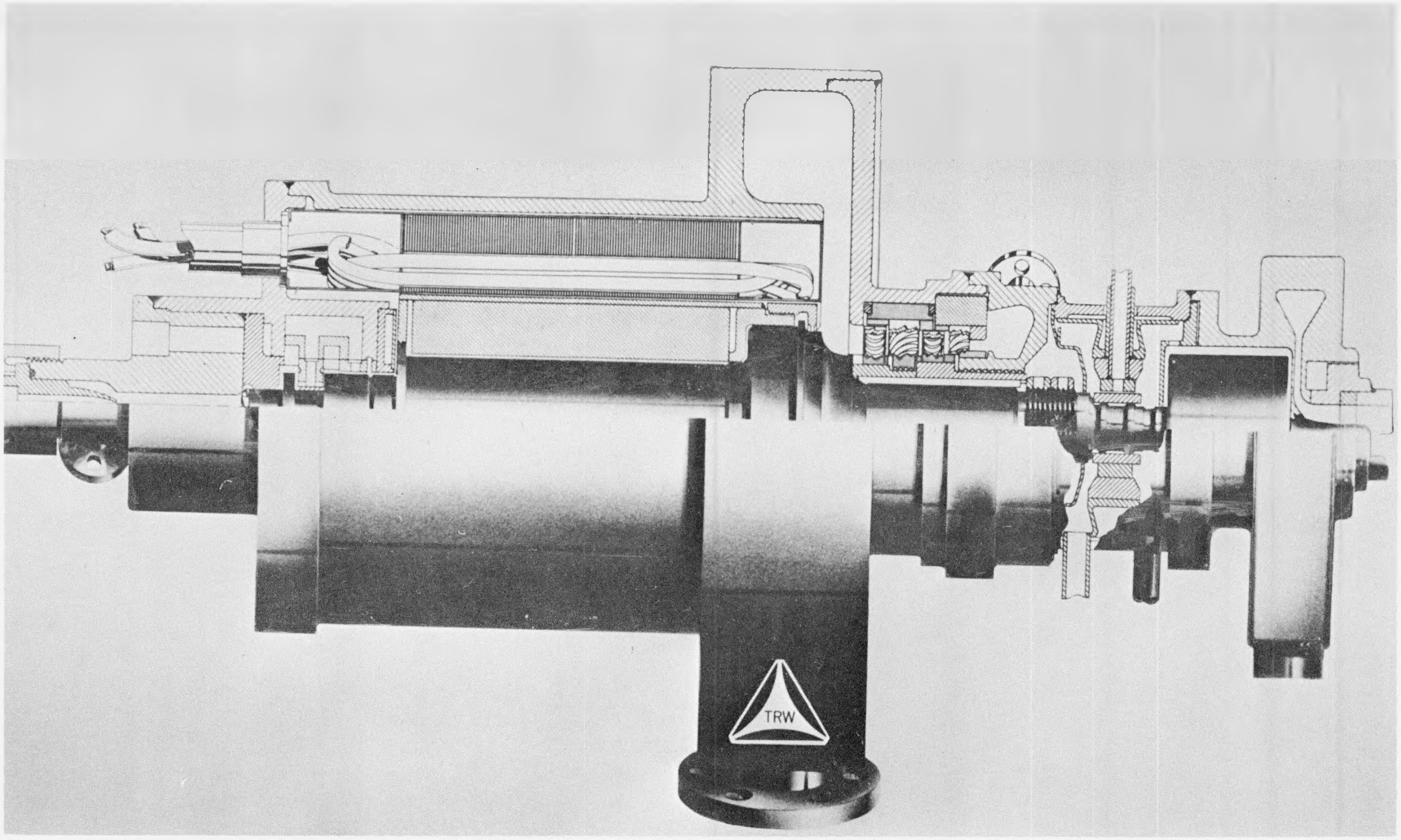

Figure 3. Combined Rotating Unit

TABLE I

SNAP 2 APU PERFORMANCE DATA

SYSTEM	
Net output	3 kw (electrical)
Voltage	110 volts single phase
Frequency	2000 cps
Voltage regulation	5% (zero to full load)
Frequency regulation	1%
Power factor	1.0 - 0.8 lagging
Distortion	7%
Weight	620 pounds including 120 pounds for vehicle structural requirements
Efficiency	6.7%
Thermal power	45 kw
Design lifetime	1 year
REACTOR	
Weight	250 pounds with control and safety systems
Coolant	sodium or sodium-potassium eutectic
Reflector	beryllium
Control	variable reflector
Coolant inlet temperature	1000°F
outlet temperature	1200°F
Effective delayed neutron fraction	0.0085
Mean neutron lifetime	15 microseconds
POWER CONVERSION	
Cycle	mercury-Rankine
Weight	250 pounds including boiler and condenser
Boiling condition	100 psia (906°F) mercury vapor superheated to 1150°F

TABLE I (Continued)

POWER CONVERSION (Continued)	
Condensing condition	6.2 psia (595°F) mercury subcooled to 425°F
Mercury flow (cycle)	16 pounds/minute
(total)	46 pounds/minute (includes bearing flow)
Radiator area	110 ft^2 available
RPM	40,000
Bearings	mercury lubricated hydrodynamic journals mercury lubricated hydrostatic thrust

Figure 4 indicates a possible vehicle configuration. The boiler is a U-tube counter flow heat exchanger encircling the vehicle at the combined rotating unit elevation. The configuration was chosen to minimize net angular momentum and hence interference with vehicle altitude control. The condenser-radiator utilized the vehicle skin as extended radiating surface for the direct condensing tubes bonded to the interior surface of the skin. The shield is located in the reactor support ring so as to shadow shield the payload. Additional unit shields are required for the more sensitive payload components (photographic film in particular).

C. SNAP 8 REACTOR CHARACTERISTICS

The performance characteristics of the SNAP 8 reactor are summarized in Table II. These performance data represent the best estimates available at present and are intended to insure uniformity of proposals. These performance estimates will be revised as the reactor design progresses.

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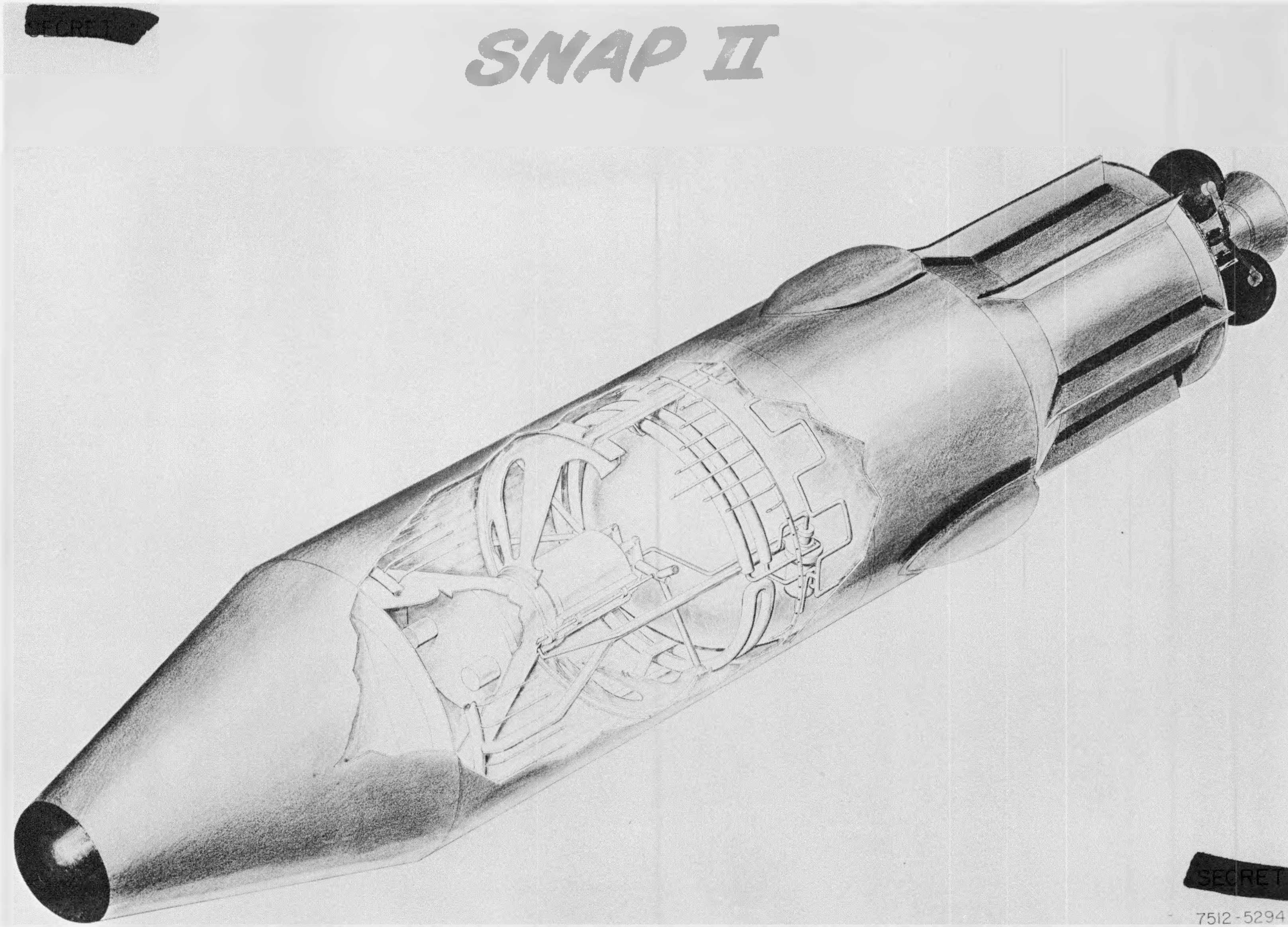

Figure 4. SNAP 2 Vehicle Installation

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TABLE II

SNAP 8 REACTOR SUMMARY

Reactor thermal power output	500 kw
Reactor gross weight (unshielded)	250-300 lb
Overall reactor envelope	13-17 in. diameter by 14-20 in. long
Estimated space required around reactor for reactor startup mechanism and shield	30 in. diameter by 36 in. long
Reactor life at full power continuous operation	1 year
Maximum reactor bulk coolant outlet temperature	1350°F
Coolant pressure drop across reactor (Na or NaK at 1200°F)	$\Delta P = 0.015\ (\text{lb/sec})^{1.8}$
Maximum allowable coolant temperature rise across core	300°F
Coolant	sodium or NaK
Coolant volume, fraction in core	0.12
Electrical power--for reactor control drive mechanism	200 watts
Prompt neutron lifetime	10^{-5} sec
Effective delayed neutron fraction	0.0085
Heat capacity of core (exclusive of reflector)	20 Btu/°F
Core thermal time constant	15 sec
Reflector heat capacity	60 Btu's/°F
Reflector thermal time constant	10 min
Equilibrium temperature coefficient of reactivity	-2×10^{-5}/°F
Fast neutron leakage current per watt of thermal power at 3 ft from center of unshielded reactor	$3 \times 10^{5} \dfrac{n}{cm^{2}\text{-sec-watt}}$
Gamma ray leakage current per watt of thermal power at 3 ft from center of unshielded reactor	$2 \times 10^{6} \dfrac{n}{cm^{2}\text{-sec-watt}}$
Average neutron flux inside core per watt of thermal power	(See following page)

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TABLE II (Continued)

Neutron Energy	Neutron Flux
0 - 0.46 ev	$2 \times 10^7 \frac{n}{cm^2\text{-sec-watt}}$
0.46 - 5 ev	$4 \times 10^7 \frac{n}{cm^2\text{-sec-watt}}$
5 - 275 ev	$8 \times 10^7 \frac{n}{cm^2\text{-sec-watt}}$
275 - 9120 ev	$9 \times 10^7 \frac{n}{cm^2\text{-sec-watt}}$
9120 ev - 0.18 Mev	$11 \times 10^7 \frac{n}{cm^2\text{-sec-watt}}$
0.18 - 0.5 Mev	$9 \times 10^7 \frac{n}{cm^2\text{-sec-watt}}$
0.5 - 1.3 Mev	$14 \times 10^7 \frac{n}{cm^2\text{-sec-watt}}$
1.3 - 3.7 Mev	$18 \times 10^7 \frac{n}{cm^2\text{-sec-watt}}$
3.7 - 6 Mev	$4 \times 10^7 \frac{n}{cm^2\text{-sec-watt}}$
6 - 10 Mev	$1 \times 10^7 \frac{n}{cm^2\text{-sec-watt}}$

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II. FACILITY

A. SNAP ENVIRONMENTAL TEST FACILITY

Many supports, such as hot cells, decontamination, radioactive waste disposal, shield testing, fuel handling, engineering development, and environmental testing facilities, are required for the development of a nuclear powered APU. However, the major unique facility pertinent to the testing of the integrated reactor-power conversion system is a large shielded cell which can contain the operating system during environmental tests. The facility being constructed for the SNAP 2 system is described below.

In contrast to other designs, the SNAP systems do not have personnel shielding as a specific system part. The test facility is therefore basically a reactor shield with the associated containment and protective systems. To perform the required testing program, the installation includes control systems, heat removal systems, remote manipulators, ventilation systems, waste storage facilities, and general laboratory facilities.

The heart of the facility is formed by two nitrogen-atmosphere power test vaults located on opposite sides of a transfer lock vault. These areas and compartments are of a single, massive concrete construction. The top of this structure is even with the ground surface and is surrounded by compacted earth. A building surmounts the vaults. Additional details are shown in Figures 5, 6, and 7.

Tests to be performed in this facility include:

a) Reactor-power conversion integration tests.

b) APU operational and endurance tests.

c) APU environmental tests including:
   1) Orbital temperature distributions
   2) Vacuum
   3) APU altitude perturbations
   4) Missile vibrations, shock and temperature transients in the case of ground startup.

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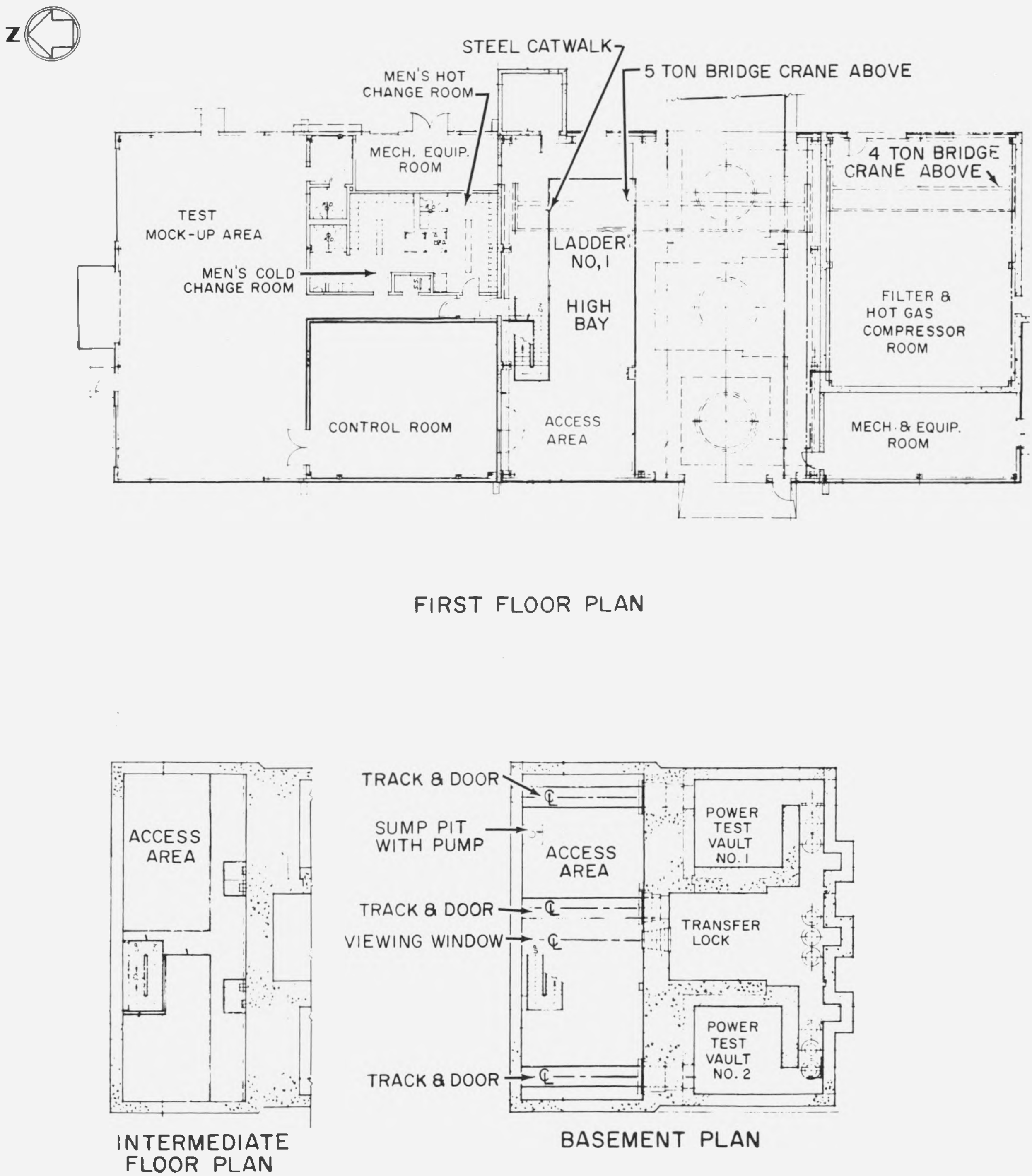

Figure 5. Environmental Test Building - Plans

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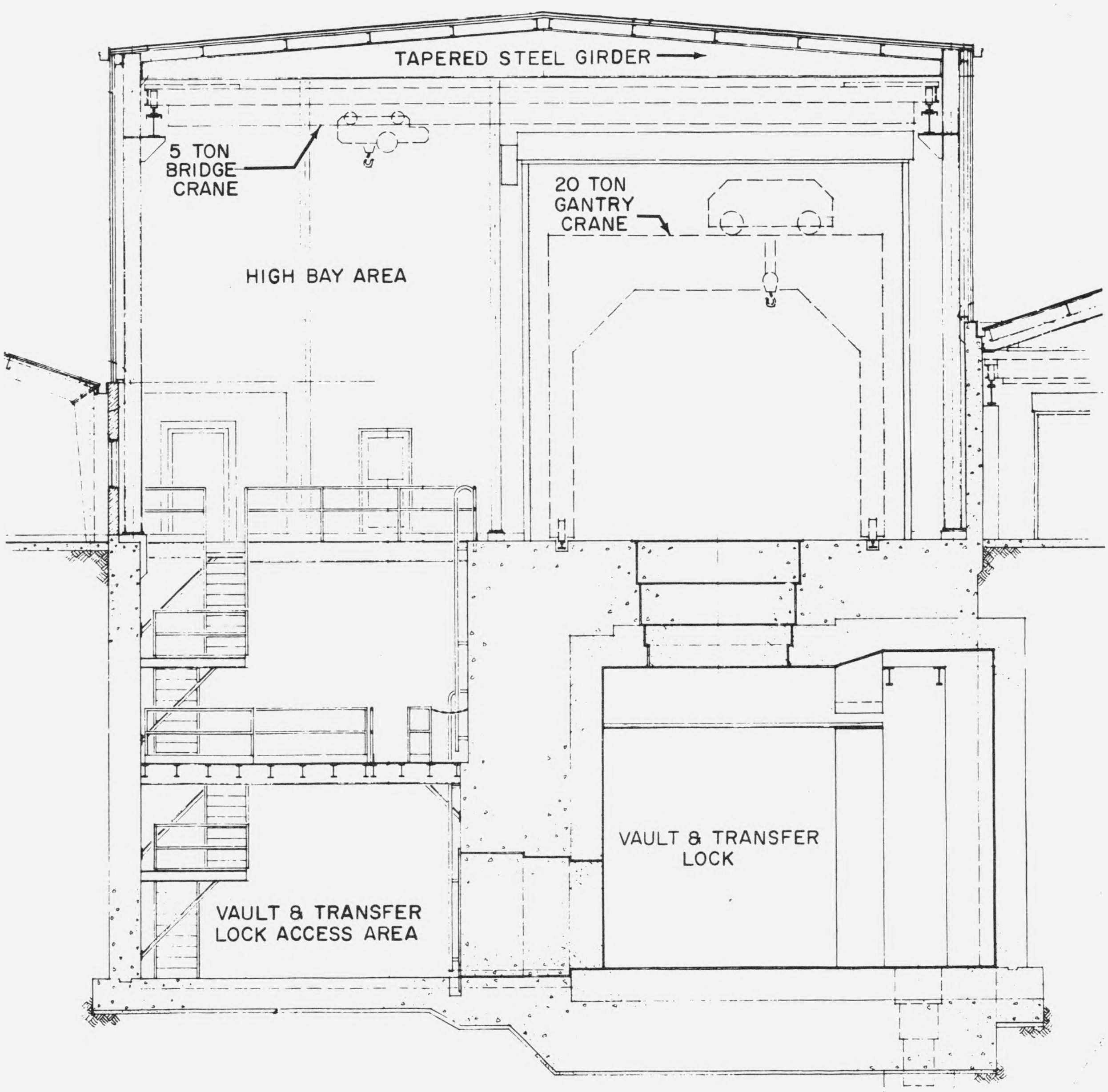

Figure 6. Building Section and Details

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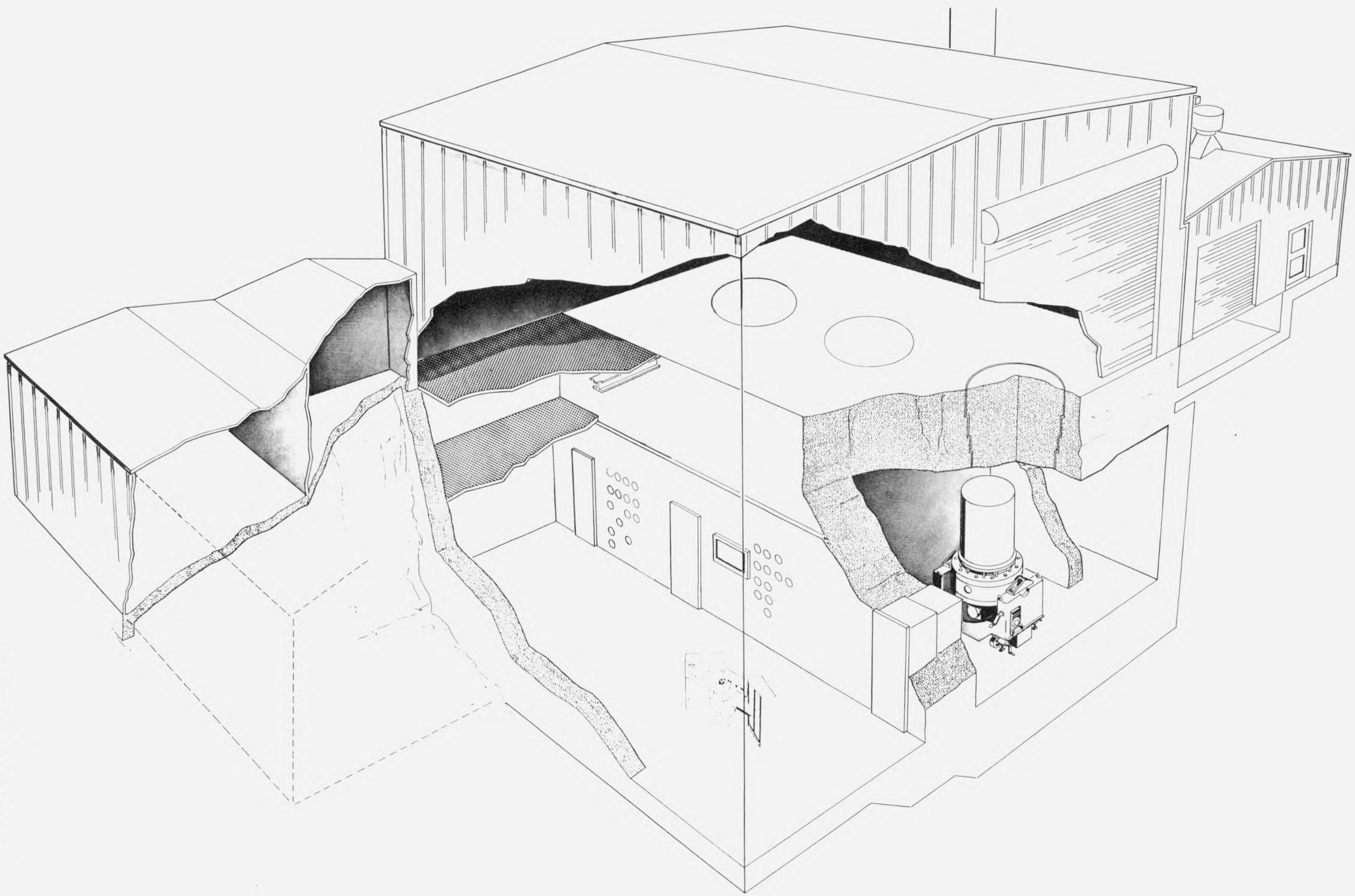

Figure 7. SNAP Environmental Test Facility (SETF)

Testing will be accomplished in the power test vaults, the transfer vault being used during test set-up and dismantling for remote handling operations, manipulator storage, etc. During test operations, the power test vault nitrogen atmosphere will be maintained at ambient pressure by a gas handling system. Energy dissipated in the vault atmosphere and in the shielding will be removed by special cooling systems. In the case of a major incident, radioactivity is contained in the vault until the vault atmosphere is processed through filters and stored in hold-up tanks and until remotely-operated devices collect particulate matter which has deposited in the vault.

Following normal testing, remote manipulators are transferred from the transfer vault to the power test vault. The equipment is dismantled and properly shielded, the vault is cleaned, and then opened for personnel access. Following final clean-up, the next test is installed.