NUREG-1119

Safety Evaluation Report
related to renewal of the operating license for the CAVALIER Training Reactor at the University of Virginia

Docket No. 50-396

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

May 1985

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ABSTRACT

This Safety Evaluation Report for the application filed by the University of Virginia for a renewal of Operating License R-123 to continue to operate the CAVALIER (Cooperatively Assembled Virginia Low Intensity Educational Reactor) has been prepared by the Office of Nuclear Reactor Regulation of the U.S. Nuclear Regulatory Commission. The facility is owned and operated by the University of Virginia and is located on the campus in Charlottesville, Virginia. Based on its technical review, the staff concludes that the reactor facility can continue to be operated by the university without endangering the health and safety of the public or the environment.

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1 INTRODUCTION

The University of Virginia (UVA/licensee) submitted a timely application to the U.S. Nuclear Regulatory Commission (NRC) for renewal of the Class 104 Operating License R-123 for its open-pool training reactor by letter (with supporting documentation) dated June 22, 1984. The letter requests renewal of the Operating License for 20 years to permit continued operation at thermal power levels up to and including 100 W. The university currently is permitted to operate the CAVALIER (Cooperatively Assembled Virginia Low Intensity Educational Reactor) within the conditions authorized in past amendments in accordance with Title 10 of the Code of Federal Regulations (10 CFR), Paragraph 2.109 until NRC action on the renewal request is completed.

The renewal application is supported by information provided in the Technical Specifications, as supplemented on December 20, 1984; the Environmental Impact Report; the Safety Analysis Report, as supplemented through December 20, 1984; and the Reactor Operator Requalification Program.

The renewal application contains the information regarding original design of the facility and includes information about modifications to the facility made since initial licensing. The licensee's approved Physical Security Plan is protected from public disclosure under 10 CFR 2.790(d)(1) and 10 CFR 9.5(a)(4).

The NRC staff technical safety review with respect to issuing a renewal operating license to UVA has been based on the information contained in the renewal application and supporting documents, site visits, and responses to requests for additional information. This material is available for review at the Commission's Public Document Room at 1717 H Street, N.W., Washington, D.C. This Safety Evaluation Report was prepared by Robert E. Carter, Project Manager, Division of Licensing, Office of Nuclear Reactor Regulation, NRC. Assistance with the technical review was provided under contract by personnel from Los Alamos National Laboratory: C. A. Linder, A. E. Sanchez-Pope, and C. L. Faust. They provided most of the input for Sections 4 through 14 of this Safety Evaluation Report (SER).

The purpose of this SER is to summarize the results of the safety review of the UVA CAVALIER reactor and to delineate the scope of the technical details considered in evaluating the radiological safety aspects of continued operation. This SER will serve as the basis for renewal of the license for operation of the UVA CAVALIER facility at thermal power levels up to and including 100 W. The facility was reviewed against the Federal regulations (10 CFR 20, 30, 50, 51, 55, 70 and 73), applicable regulatory guides (Division 2, Research and Test Reactors), and appropriate accepted industry standards (American National Standards Institute/American Nuclear Society (ANSI/ANS) 15 series). Because there are no accident-related regulations for research reactors, the staff has at times compared calculated dose values with related standards in 10 CFR 20, "Standards for Protection Against Radiation," both for employees and the public.

The initial CAVALIER operating license was issued on September 24, 1974, authorizing operation at thermal power levels up to and including 100 W. Since initial

licensing, the CAVALIER has been operated and used intermittently as a teaching/training facility in the university's nuclear engineering programs. Utilization frequency and total integrated energy production have produced insignificant thermal cycling and insignificant fission product inventory in the fuel.

Plate-type reactors--using essentially the same kind of fuel, similar control rods and drive systems, and similar safety circuitry as the UVA CAVALIER--have been constructed and operated in many countries of the world, including the United States where there are more than 50 such reactors. Since the first of this type of reactor was assembled in 1950, there have been no reported events that caused significant radiation risk to public health and safety. Most plate-type reactors have annual MW hours of operation many orders of magnitude greater than the CAVALIER, both because of different types of utilization and because of higher operating power levels. The staff operating the CAVALIER devote most of their efforts to operating a 2 MW reactor in the same engineering building (see Docket No. 50-062, Operating License R-66).

1.1 Summary and Conclusions of Principal Safety Considerations

The staff evaluation considered the information submitted by the licensee, past operating history recorded in annual reports submitted to the Commission by the licensee, written reports by NRC Region II, discussions with Region II staff, and onsite observations. In addition, as part of the licensing review, the staff obtained laboratory studies and analyses of credible accidents postulated for the plate-type, nonpower reactor.

The principal matters reviewed for the CAVALIER and the conclusions reached were the following:

(1) The design, testing, and performance of the reactor structure and the systems and components important to safety during normal operation were adequately planned, and safe operation can reasonably be expected to continue.

(2) The expected consequences of several postulated credible accidents have been considered, emphasizing those likely to cause loss of integrity of fuel-element cladding. The staff performed conservative analyses of the most serious hypothetically credible accidents and determined that the calculated potential radiation doses outside of the reactor site are not likely to exceed the guidelines of 10 CFR 20 for doses in unrestricted areas.

(3) The licensee's management organization, conduct of training and research activities, and security measures are adequate to ensure safe operation of the facility and protection of special nuclear material.

(4) The systems provided for control of radiological effluents can be operated to ensure that releases of radioactive wastes from the facility are within the limits of the Commission's regulations and are as low as reasonably achievable (ALARA).

(5) The licensee's Technical Specifications, which provide operating limits controlling operation of the facility, are such that there is a high degree of assurance that the facility will be operated safely and reliably.

(6) The financial data and information provided by the licensee are such that the staff has determined that the licensee has reasonable access to sufficient revenues to cover operating costs and eventually to decommission the reactor facility.

(7) The licensee's program, which provides for the physical protection of the facility and its special nuclear material, complies with the applicable requirements of 10 CFR 73.

(8) The licensee's procedures for training its reactor operators and the plan for operator requalification are adequate; they give reasonable assurance that the reactor facility will be operated competently.

(9) The licensee's Emergency Plan provides reasonable assurance that the licensee is prepared to assess and respond to potential emergency events.

1.2 Reactor Description

The CAVALIER is a heterogeneous, swimming-pool-type reactor. The core is cooled by natural convection of light water, moderated by water, and reflected by water and/or graphite. The reactor core is located near the bottom of a square water-filled tank that has inner dimensions of approximately 1.7 m and a depth of 3.35 m. The core grid plate is supported by the tank bottom, and the control systems are suspended from a steel framework above the reactor tank.

The reactor core normally contains 16 fuel elements positioned in holes in an aluminum grid plate that contains a 4 by 7 array of holes to allow changing fuel element configurations and control rod locations. The fuel elements consist of several thin metal plates assembled into a unit about 7.6 by 7.6 cm with an active fuel length of approximately 0.6 m. Fuel elements of this general configuration were first designed for and used in the Materials Testing Reactor (MTR) and subsequently are referred to as MTR-type fuel.

Reactivity of the reactor core is changed by the operator by moving the control rods that are driven through fail-safe magnetic clutches located on the support structure. The ionization chambers used for sensing neutron and gamma-ray flux densities are suspended near the core. The control console is located in a section of the reactor room from which the operator can observe the top structures of the reactor. The control console consists of typical read-out and control instrumentation.

1.3 Reactor Location

The CAVALIER is housed in the nuclear reactor wing of the Department of Nuclear Engineering on the campus of the university, approximately 700 m west of the city limits of Charlottesville, Albemarle County, Virginia. The reactor is located in a remote part of the campus, approximately 3 km from the downtown business district of the city of Charlottesville. The reactor building is constructed of conventional masonry, built on sloping land, and is partially underground.

1.4 Shared Facilities and Equipment and Special Location Features

The reactor room is attached to the Nuclear Engineering laboratories, dedicated primarily to university education, training, and research. Utilities such as

municipal water and nonradioactive sewage, natural gas, and electricity are provided for common use in the entire building.

The reactor room shares its ventilation control system with other laboratory spaces. The nearest occupied building that is not part of the reactor facility, yet still on the campus, is a nuclear physics research laboratory about 125 m from the location of the reactor.

The CAVALIER is managed and operated by the same personnel who are responsible for a licensed, 2-MW research reactor also located in the Nuclear Engineering Building. These reactors share such items as supplies, equipment, instrumentation, and storage of unirradiated fuel, as appropriate. See NUREG-0928 for a description of the University of Virginia's open-pool research reactor (UVAR).

1.5 Comparison with Similar Facilities

The fuel used in the CAVALIER is based on the MTR design and is very similar to the fuel used in approximately 50 other nonpower reactors operating in the United States and more than 25 reactors operating in foreign countries. The control and instrumentation systems, while different in detail, are based on the same operating principles used for these 75 other research or test reactors.

2 SITE CHARACTERISTICS

2.1 Geography

The CAVALIER facility is located on a sparsely developed part of the campus of the University of Virginia, approximately 700 m west of the city limits of Charlottesville, County of Albemarle, Commonwealth of Virginia. The site is located at an elevation of about 200 m at an abandoned reservoir in a valley between two small mountains, approximately 3 km from the downtown business district of Charlottsville. Figure 2.1 shows the location of the CAVALIER with respect to the Charlottesville area, and Figure 2.2 shows the contours of the site, the location of the exclusion fence, and the nearest offsite occupied building, a nuclear research laboratory. The next nearest occupied buildings are a radio-astronomy research laboratory and university student's dormitories at about 250 and 325 m, respectively, from the site.

2.2 Demography

Except for Charlottesville and the university campus, there are no other large population centers within Albemarle County, which surrounds the reactor site for more than 16 km in all directions. The land use in the county is mainly for agriculture, so the population density is typically low density rural. The highest concentration of the Charlottesville residents and the majority of the city's population live in the range between about 1.5 to 5 km east of the reactor site. The nearest occupied dwelling is the student's dormitories.

2.3 Nearby Industrial, Transportation, and Military Facilities

2.3.1 Transportation Routes

The reactor site is in a rugged hilly section of the campus. There is no major highway or railway within hundreds of meters; the closest roads are not heavily travelled. The small Charlottesville airport, lightly used by commercial planes, is more than 15 km from the reactor site.

2.3.2 Nearby Facilities

There are no large industries or major military establishments in the Charlottesville area that cause heavy use of local transportation systems.

2.3.3 Conclusion

Because there are no industrial or military facilities near the reactor site that could directly or indirectly cause accidental damage to the reactor facility, the staff concludes that the only accidents that need be evaluated in detail in considering the safety of the public are those that might originate from within the reactor facility. These are discussed in Section 14 of this SER.

Figure 2.1 Population density distribution (1968)
(each dot = 10 persons)

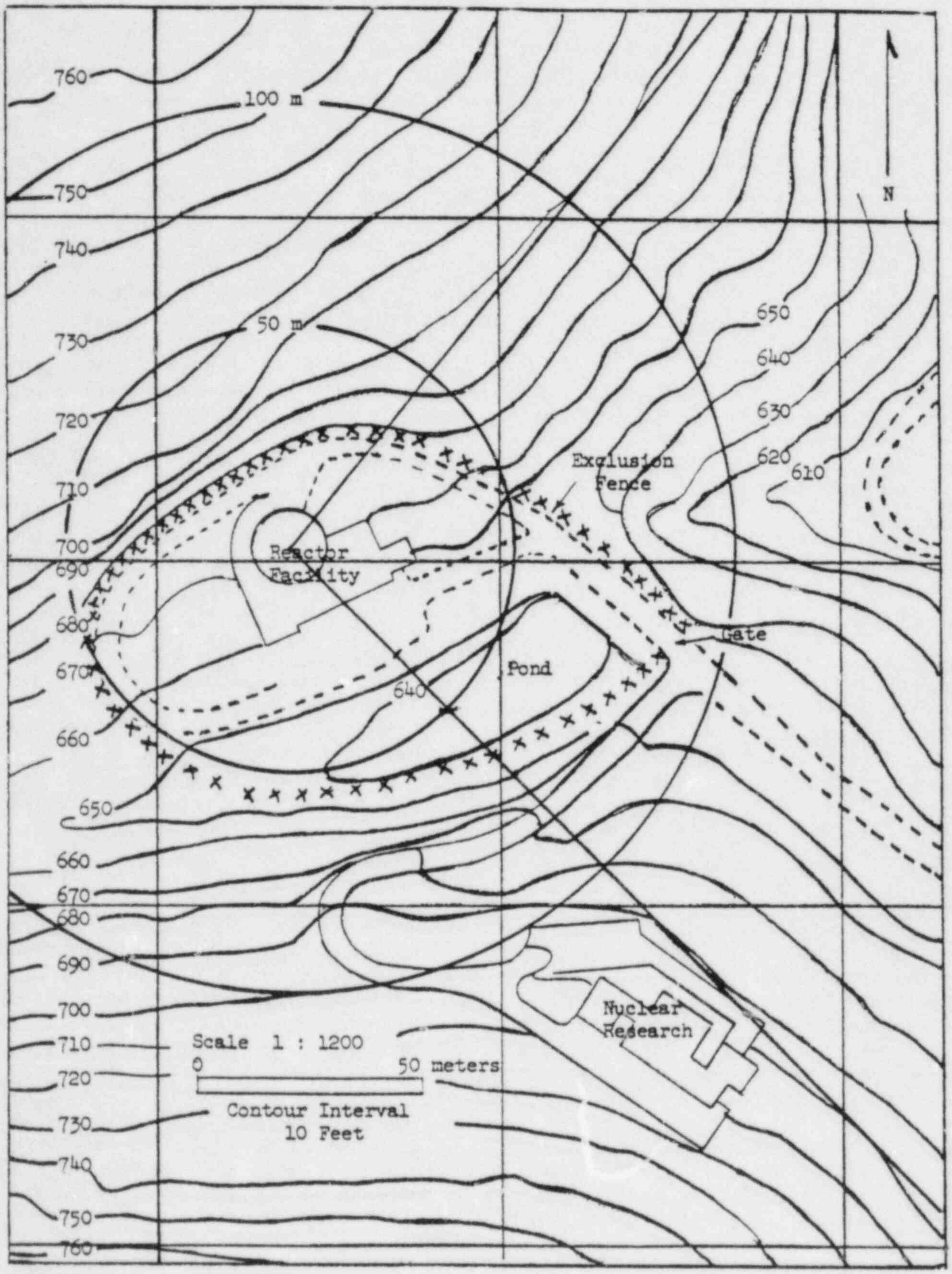

Figure 2.2 Contour map of CAVALIER site with exclusion fence

2.4 Meteorology

UVA lies in the western region of the Piedmont Plateau, in the eastern foothills of the Blue Ridge Mountains of the Appalachian complex. The site has a continental climate, moderated by the proximity of the Atlantic Ocean.

For most of the year, winds from the northern quadrant predominate, with a secondary maximum frequency of winds from the south and southwest, whereas winds from the east and southeast are relatively rare. In winter, the primary maximum frequency of wind directions lies in the northeastern quadrant with an isolated maximum for winds from the west. In summer, winds from the southern quadrant show a primary maximum, and those from the northeast a secondary maximum. The frequency of calm or stagnant wind conditions is relatively low during all seasons of the year except in summer.

These meteorological features are generally the result of the predominant anticyclonic circulation over the northern portion of the country during the winter, and the semipermanent Atlantic High which moves northward and eastward in the spring. These larger features are locally moderated by the generally northeast-to-southwest course of the Appalachian Mountain chain and its valleys.

Tropical storms generally move northward off the Atlantic coast and sometimes influence weather in Charlottsville, but tornadoes are not frequent in this area.

2.5 Hydrology

The reactor building is constructed on the side of a small ravine, or draw, between two mountains, some 15 m above an artificial pond that was originally dammed to be used as a reservoir. In this location, the building is well above the flood plain and not low enough in the ravine to be in the path of credible flash floods caused by heavy rainfall in the small mountains. The pond waters can be released into Meadowbrook Creek which flows into the Rivanna River. In case of failure of the reactor tank, the pond will serve as a temporary holding basin for the water.

2.6 Geology and Seismology

The reactor site is located near the boundary between the Blue Ridge and Piedmont provinces, which are a part of the Appalachian orogen. The basic framework of the Appalachian orogen consists of a low-angle megathrust system, which underlies the Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain provinces of the eastern United States, going from west to east. An important feature of this system is the fact that the igneous and metamorphic rocks of the Blue Ridge and Piedmont have been thrust westward over a large segment of the Paleozoic sedimentary rocks of the Valley and Ridge province.

The structure in the site region consists of a series of major thrust sheets where crystalline rocks of the Blue Ridge have overridden a 48-56 km-wide wedge of Paleozoic sedimentary rocks ranging from the Cambrian Chilhowee Group to the Ordovician Martinsburg Shale. The burial of the sedimentary rocks and the development of the Blue Ridge occurred during the Alleghenian orogeny (300-240 million years before present).

Approximately 165 felt earthquakes have occurred in Virginia since 1774. The largest historical earthquake within 50 km of Charlottesville was the maximum

Modified Mercalli intensity (MMI) VII of December 23, 1875. The largest historical earthquake in Virginia was the maximum MMI VIII event of May 31, 1897. This earthquake was in Giles County, Virginia, at a distance of approximately 200 km from Charlottesville.

The highest intensity reported in Charlottesville from historical earthquakes is MMI VI from the August 31, 1886, earthquake in Charleston, South Carolina, and the December 26, 1929, earthquake in central Virginia. MMI VI is described as: damage slight, a few instances of fallen plaster or damaged chimneys. On the basis of the historical seismicity, it appears that earthquakes do not pose a significant hazard to well constructed buildings in the Charlottesville area.

2.7 Conclusion

The staff has reviewed and evaluated the CAVALIER site for both natural and man-made hazards and concludes that the site is acceptable for the continued operation of the reactor.

3 DESIGN OF STRUCTURES, SYSTEMS, AND COMPONENTS

The licensee's Safety Analysis Report provides information on the design, construction, and functions of the as-built reactor building, reactor systems, and auxiliary systems.

3.1 Reactor Facility Layout

The CAVALIER is located in the reactor wing of the University of Virginia Nuclear Engineering Building, which also houses the UVAR. However, the reactors are in separate rooms and operate independently and no neutronic interaction or hazard coupling between the CAVALIER and the UVAR is considered credible. The reactor facility consists of a main reactor containment room that houses the UVAR, a radiation laboratory, a counting room, an electronic shop, a machine shop, and a student training laboratory that houses the CAVALIER. Figure 3.1 shows the floor plans for the three levels of the reactor facility.

3.2 Wind Damage

Meteorological data indicate a low frequency of tornadoes and effects of tropical disturbances, but a moderately high frequency of summer thunderstorms. However, the reactor tank sits in a concrete-walled pit in a reinforced masonry building located partially below grade. The open tank and reactor building operate at atmospheric pressure, so loss of integrity of either resulting from wind damage could lead to nonexplosive collapse. In turn, loss of tank water might occur; however, the licensee's analysis, with which the staff agrees (see Section 14), provides adequate assurance that loss of coolant would not lead to melting of any fuel.

3.3 Water Damage

The reactor building is situated in the side of a well-drained hill, above the flood plain, and adequately above the level of potential flash flood waters in the ravine.

3.4 Seismic-Induced Reactor Damage

The CAVALIER tank system would not resist damage resulting from significant seismic activity. However, no detailed seismic analysis has been performed, for which there are two justifications: (1) Charlottesville is in a region of historically low seismic activity and (2) damage to the reactor tank and loss of coolant would not result in melting of fuel or the release of significant quantities of fission product radioactivity in the event of physical damage to fuel plates (see Section 14).

3.5 Mechanical Systems and Components

The mechanical systems of importance to safety are the neutron-absorbing control rods suspended from the superstructure. The motors, gear boxes, magnetic clutches, switches, and wiring are above the level of the water and readily

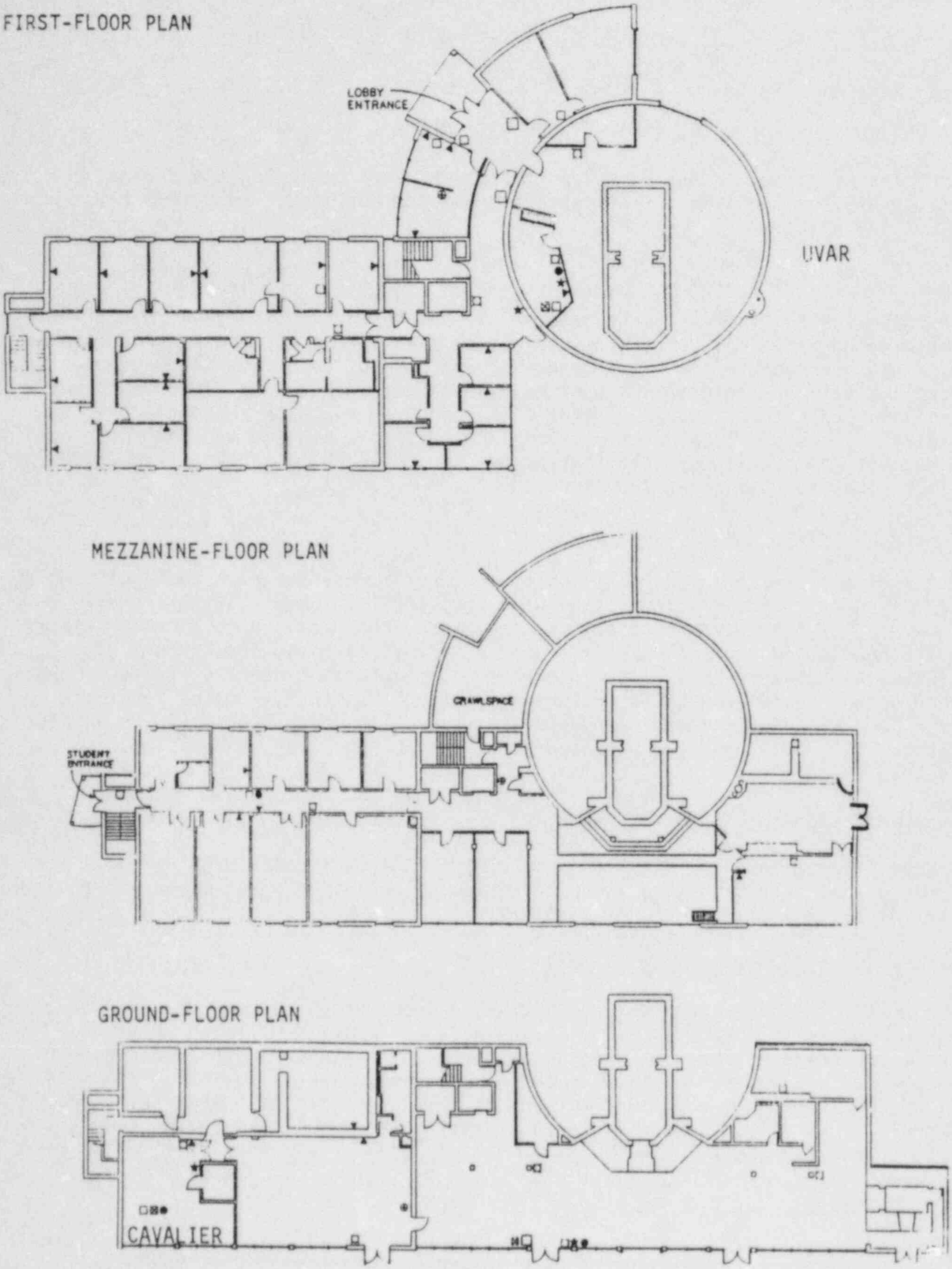

Figure 3.1 Plans for nuclear reactor facility

accessible for testing and maintenance, which is performed on an acceptable schedule. Interruption of electrical power or mechanical damange to control systems would lead to pressure gravity insertion of control rods and reactor shutdown.

3.6 Conclusion

The UVA reactor facility was designed and built to withstand adequately all credible and likely wind, water, and seismic damage associated with the site. On the basis of the considerations above and in Section 14, the staff concludes that damaging natural events have a small likelihood of occurring and small consequences if they did. Therefore, the staff concludes that there is reasonable assurance that natural events at the site do not pose a significant risk to the public from reactor damage.

4 REACTOR

The University of Virginia Cooperatively Assembled Virginia Low-Intensity Educational Reactor (CAVALIER) is a pool reactor that is operated at a maximum power level of 100 W. The CAVALIER may be either graphite or water reflected, and uses MTR-type fuel elements that also are authorized to be used in the UVA 2 MW research reactor (UVAR) core. The CAVALIER power level is controlled by inserting or withdrawing the neutron-absorbing control rods.

The CAVALIER initially attained criticality in 1974. It is used principally as an educational and training facility and for low-flux experimental research. The design and performance characteristics of the CAVALIER are summarized in Table 4.1.

4.1 Reactor

The CAVALIER tank is located inside a 2.74-m-deep concrete pit in the ground floor of the Student Laboratory. An aluminum moderator tank, 1.7 m^2 and 3.35 m deep, standing 0.91 m above ground level, contains the CAVALIER core and shield water. A cleanup demineralizer for the CAVALIER water also is located in the reactor pit and is separated from the moderator tank by a concrete block wall 0.91 m thick (see Figure 4.1).

4.1.1 Reactor Core

The CAVALIER grid configuration consists of a 4 by 7 lattice where vertically oriented fuel elements and control rods are immersed in an open tank of demineralized water that serves as a neutron moderator and reflector and as a radiation shield.

At the time of this review there were no fuel elements or control rods loaded in the CAVALIER core. When the CAVALIER is refueled, the core is expected to duplicate the most recent loading, consisting of twelve standard curved-plate fuel elements, four control rod fuel elements, four control rods, and aluminum wire mesh boxes surrounding the core on three sides for a water-reflected geometry containing ~2.7 kg of ~93% enriched ^{235}U. The planned CAVALIER core configuration is shown in Figure 4.2.

4.1.2 Reflector Assembly

The CAVALIER is authorized to operate with either a graphite- or water-reflected core. However, no graphite elements are available at present. The normal configuration is a water-reflected geometry with aluminum wire mesh boxes mounted along the sides of the core to prevent objects that might add reactivity from being dropped inadvertantly next to the core. On one side, special nonfuel-bearing elements, which include irradiation baskets and instrument tubes, may replace the aluminum boxes.

The graphite-reflected geometry would be achieved by replacing the wire mesh boxes with closed aluminum boxes filled with graphite bars.

Table 4.1 Principal design parameters

Parameter	Description
Reactor type	Open-pool, MTR-type fuel
Maximum licensed power level	100 W
Fuel Element Design*	
Fuel material	U-Al_x alloy clad with Al
Uranium enrichment	~93% ^{235}U
Shape	Curved plate
Length	34.4 in. (0.87 m)
Width	2.94 in. (7.47 cm)
Cladding thickness	0.015 in. (0.038 cm)
Uranium inventory	
Weight ^{235}U/fuel element	195 g (standard element) 98 g (control rod element)
Number of fuel elements	16 (12 standard, 4 control)
Reactivity Worths*	
Excess reactivity	$\leq$ 1.6% $\Delta k/k$ (2.00$) above cold, clean, critical condition
Control rods (4)	~4.0% $\Delta k/k$ (5.00$) (total)
Reactor cooling	Natural convection of bulk coolant
Reflector	Graphite or water
β_{eff}	0.8%
Reactivity Coefficient	
Temperature coefficient	-3.13×10^{-4} $\Delta k/k/^{\circ}C$
Void coefficient	-1.90×10^{-3} $\Delta k/k$/% void

*Expected values for next core configuration loading.

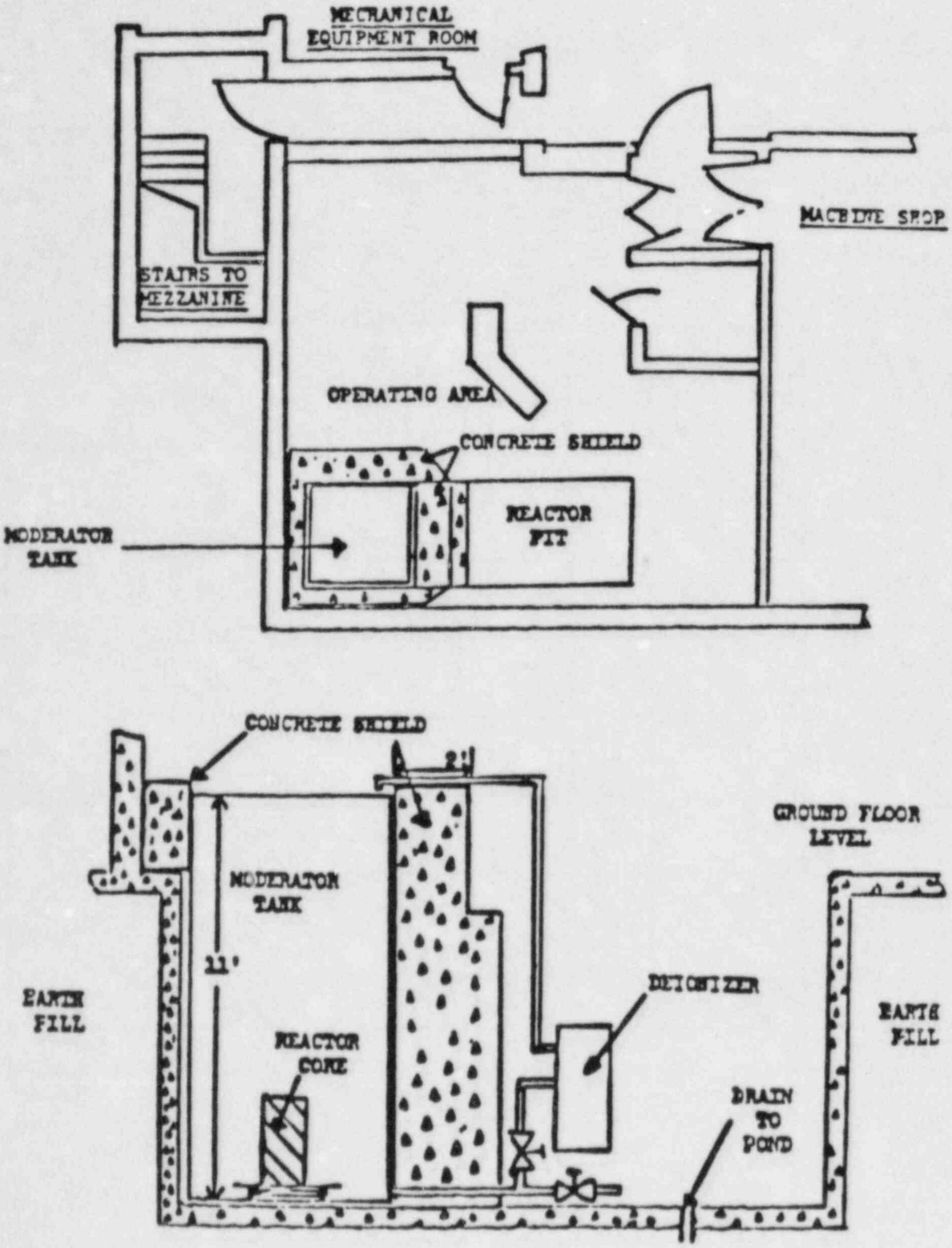

Figure 4.1 CAVALIER facility details

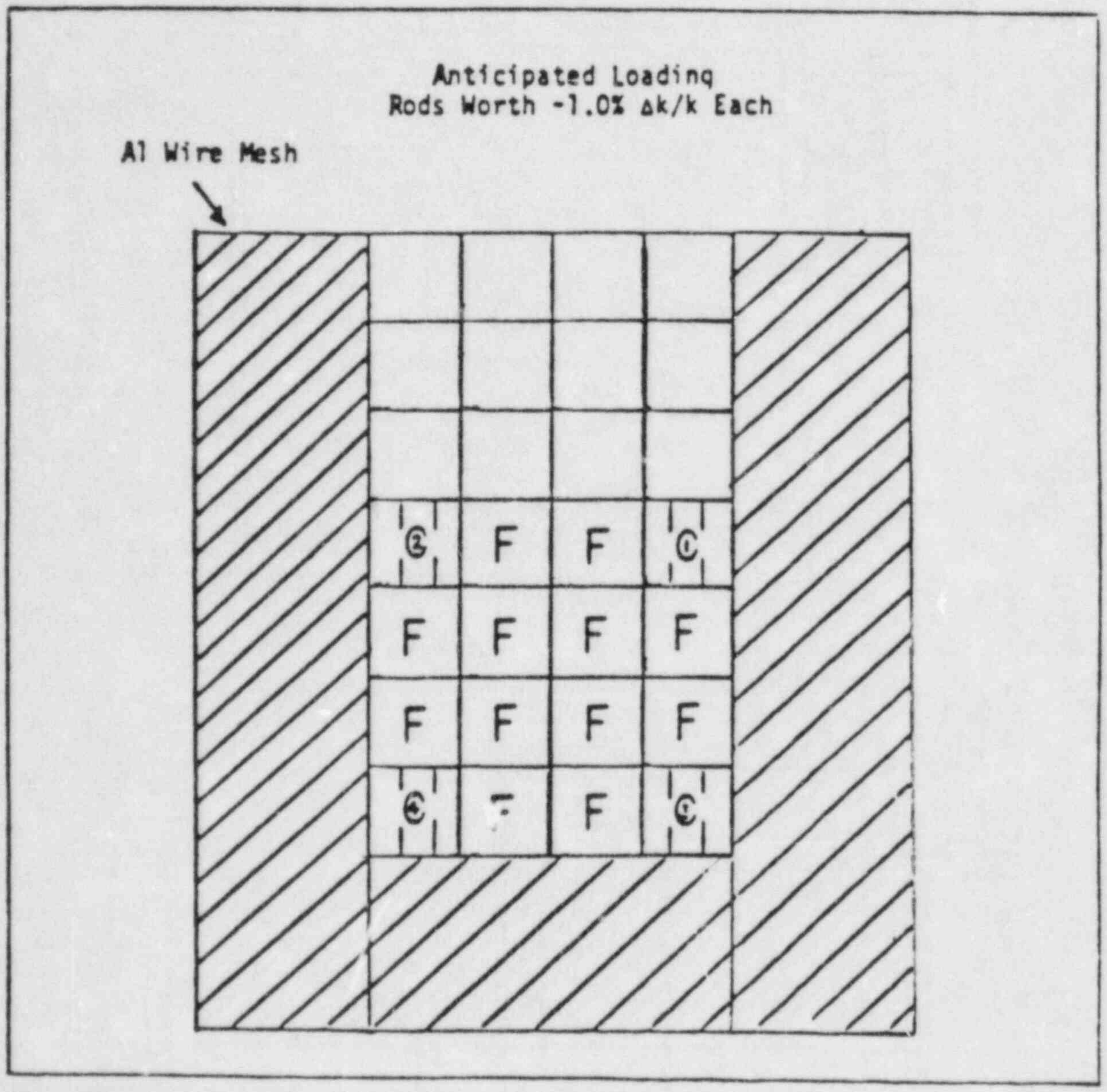

Figure 4.2 CAVALIER expected core configuration

4.1.3 Fuel Elements

The CAVALIER operates with curved-plate MTR-type fuel elements identical to those used in the UVAR core. The plates of these elements are sandwiches of aluminum cladding over uranium-aluminum alloy "meat" ~0.051 cm thick and 0.6 m long. The fuel elements are ~0.87 m long, 7.62 cm wide, and 7.62 cm thick. A standard fuel element is shown in Figure 4.3.

Each standard curved-plate fuel element consists of 18 fuel-bearing plates, and the control rod element contains 9 fuel-bearing plates. The coolant gap in the curved-plate elements is 0.31 cm wide. The control rod elements have the center nine plates removed to allow space for inserting the control rod. A partial element contains nine fuel-bearing plates alternating with nine nonfuel-bearing aluminum plates. The standard curved-plate fuel element contains ~195 g of ^{235}U, and the control rod or partial element contains ~98 g of ^{235}U. A control rod element is shown in Figure 4.3.

4.1.4 Control Rods

The CAVALIER reactivity is controlled by the vertical movement of four identical control rods that are driven in and out of the core by the control rod drive mechanisms and fall into the core when a scram signal is initiated.

Each control rod contains boron stainless steel as the poison and is clad with aluminum. Each of the rods fits into a central gap provided in a special control rod fuel element that may be located in any core position, within the reactivity limits imposed by the facility Technical Specifications.

4.2 Support Structures

The CAVALIER core is supported on a grid assembly that is mounted on the bottom of the aluminum moderator tank and bolted securely to it. The control rod drive assemblies are supported by a steel framework mounted on top of the moderator tank and centered above the grid plate.

4.3 Neutron Source

The CAVALIER uses a 1-Ci PuBe startup neutron source. The neutron source is enclosed in an aluminum tube that extends into the wire mesh aluminum screens or the graphite reflector alongside the core. A motor drive mechanism allows the neutron source to be inserted or withdrawn from the control console during reactor operations.

4.4 Reactor Instrumentation

Operation of the CAVALIER is monitored by two neutron source range channels, a log-N neutron power range channel, and a gamma power range channel. The source range channels incorporate BF_3 detectors, and the log-N channel uses a compensated ion chamber (CIC). The gamma power range (log-G) channel uses two uncompensated ion chambers (UIC) mounted within the water at opposite ends of the moderator tank. In addition, an area monitoring system uses independent gamma-ray sensors located above the moderator tank, in the equipment area of the reactor pit, and in the operating area near the control console, respectively. Additional details of the reactor instrumentation are discussed in Section 7 of this report.

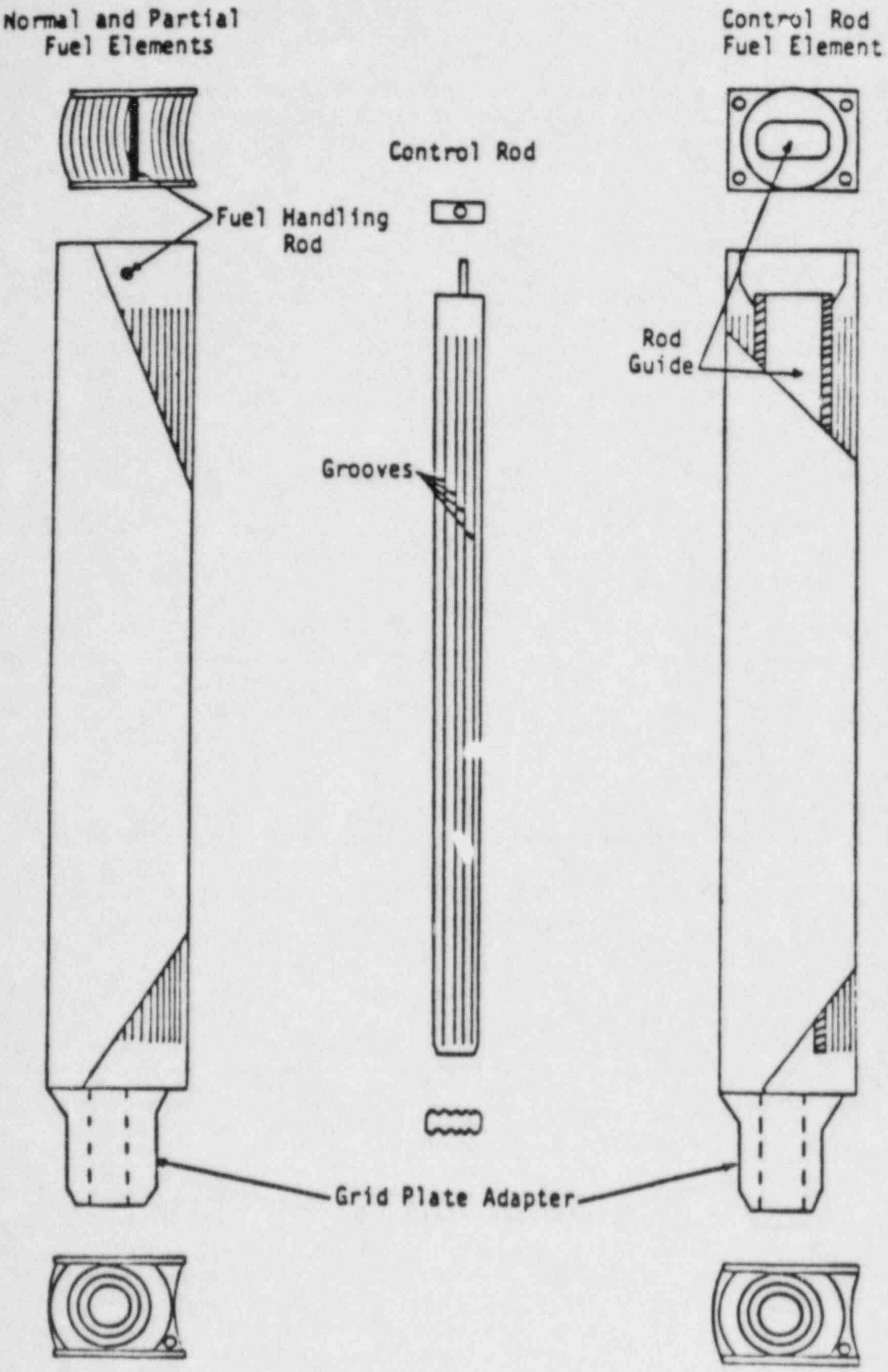

Figure 4.3 CAVALIER standard and control rod fuel element

4.5 Biological Shield

The water in the moderator tank also serves as the primary biological shield for the reactor. The Technical Specifications require that the moderator water level be >1.91 m above the top of the core for reactor operation. Additional shielding is provided by the surrounding concrete (0.91 m thick) that isolates the moderator tank from the control console area, the rest of the reactor pit, and the demineralizer.

Additionally, the mezzanine-level floor of the laboratory directly above the CAVALIER is composed of a 0.2-m-thick prestressed concrete slab with a 5 cm top, providing added shielding to the laboratory from the CAVALIER radiations.

4.6 Dynamic Design Evaluation

The safe operation of the CAVALIER is accomplished by a reactivity control system using poison-bearing control rods that are manipulated in response to measured changes in parameters provided by the instrument channels, such as neutron flux (power). Additionally, interlocks (for example, low counting rate) prevent reactor startup, and a scram system initiates rapid, automatic shutdown when a preset limit is reached.

Additional reactor stability is provided by the negative temperature coefficient of reactivity and the void coefficient, which are -3.13×10^{-4} Δk/k/°C and 1.90×10^{-3} Δk/k/% void, respectively. These are inherent nuclear safety features that are operable even if the control rods or any of the reactor protection system, instrumentation system, or additional shutdown mechanisms [such as the alternate reactivity insertion system (ARIS)] are not actuated for any reason or if operator error violates established operating procedures.

4.6.1 Excess Reactivity and Shutdown Margin

With the maximum worth experiments in place, the CAVALIER Technical Specifications limit the maximum excess reactivity above cold, clean critical to no more than 1.6% Δk/k (2.00$), and the minimum shutdown margin with the highest worth rod fully withdrawn to greater than 0.4% Δk/k. The total control rod worth is ~4.0% Δk/k in the expected core configuration, and the highest worth rod is ~1.0% Δk/k fully withdrawn. Thus, the minimum shutdown margin would still be maintained even if the core were loaded up to 2.6% Δk/k above critical. Therefore, the limit of 1.6% on excess reactivity is a constraint on reactivity conditions and helps assure conservative operating conditions of the CAVALIER. With the expected core configuration, insertion of all four control rods would make the reactor, when shut down, subcritical by at least 2.4% Δk/k. In addition, the ARIS is capable of shutting down the reactor independently of the instrumentation safety system. The ARIS injects a tank full of borated solution into the moderator tank that is sufficient to overcome more than 1.6% Δk/k excess reactivity in the core. The ARIS is required by the Technical Specifications to be operable during reactor operation and is discussed as an engineered safety feature in Section 6.

4.6.2 Assessment

Based on the above considerations, the staff concludes that reactivity addition to the CAVALIER is limited sufficiently by the Technical Specifications to

ensure that there is an adequate amount of shutdown margin available so that even in the unlikely event that the highest worth rod fails to insert when receiving a scram signal, there is still sufficient capability to shut down the reactor. The limits on the experiments are such that they preclude any prompt reactivity excursion caused by accidental experiment malfunction. The negative temperature and void coefficients provide additional potential shutdown capability if all the control rods fail to insert. Additionally, the ARIS is a backup safety feature that will provide enough negative reactivity to overcome the licensed excess reactivity in the core.

4.7 Functional Design of Reactivity Control System

The CAVALIER is controlled by manipulating four control rods in response to reactivity changes in the core. The rods can be, and are authorized to be located in any core position, consistent with Technical Specification limits on reactivity.

4.7.1 Control Rod Drive

Control rod movement is achieved by electromechanical rack-and-pinion drive units. Each drive mechanism has a three-position switch activated at the control console. Rod position indicators also are located on the console. Scram action of each rod is controlled by a magnetic clutch. Any scram or loss-of-power condition will deenergize the clutches, causing the rods to insert by gravity into the core and shut down the reactor. The reactor parameters that can initiate a scram are

(1) low moderator tank water level
(2) low startup count rate (2 channels)
(3) high reactor power level (CIC)
(4) high reactor power level (UIC)
(5) short reactor period (CIC)
(6) short reactor period (UIC)
(7) high radiation level at tank top

The control rod drive system, as well as the scram circuitry and interlock functions, are discussed in more detail in Section 7.

4.7.2 Assessment

The CAVALIER is equipped with safety and control systems typical of many small nonpower reactors. There is sufficient redundancy of control rods and diversity of scram-initiating sensors to give reasonable assurance of a safe shutdown. On the basis of the above information and the additional details in Section 7, the staff concludes that the reactivity control systems of the CAVALIER are designed and will function to ensure acceptable shutdown capabilities for the CAVALIER.

4.8 Operational Procedures

The CAVALIER is operated by NRC-licensed personnel in accordance with written procedures approved by the Reactor Safety Committee. These procedures ensure that the reactor is not operated unless the appropriate safety-related components are operable. These procedures include normal operation and shutdown of

the reactor, as well as procedures that include responses to specific events (for example, emergencies, malfunctions, and so on).

4.9 Conclusion

On the basis of the above information, the staff concludes that the CAVALIER was designed and built in accordance with good industrial practices, that the performance capability of the control and safety instrumentation is acceptable, and that the operating limits imposed by the Technical Specifications combine to provide reasonable assurance of the continued safe operation of the CAVALIER.

5. REACTOR COOLANT SYSTEM

5.1 Reactor Core Cooling System

The CAVALIER core is submerged in approximately 2000 gal (7572 L) of demineralized water in an aluminum tank and is cooled by natural convection of the bulk coolant. Because of the low power level of the reactor ($\leq$100 W), no significant rise in either the fuel or the coolant/moderator temperature occurs as a result of reactor operation, so no heat removal provisions other than evaporation are made. The moderator tank is shown in Figure 4.1.

5.2 Coolant Purification and Makeup Systems

Figure 4.1 also shows the reactor coolant/moderator purification system. A mixed-bed deionizer using throw-away resins is used to maintain conductivity of the water in the CAVALIER tank at $<5 \times 10^{-6}$ mhos/cm. The moderator tank water is pumped continuously through the deionizer at ~5 gal/min (0.18 L/s). Demineralized makeup water to replace evaporation losses is supplied from the large demineralizer system that serves the UVAR. Discharged resin from the CAVALIER demineralizer is considered as potentially radioactive and is monitored to determine if it must be disposed of as contaminated waste.

5.3 Conclusions

The staff concludes that the reactor coolant system is adequate to cool the core under all anticipated operational conditions. The staff further concludes that the coolant demineralizer is adequate to preclude significant corrosion damage to the reactor components during continued reactor operation.

6 ENGINEERED SAFETY FEATURES

Engineered safety features (ESF) are systems provided to mitigate the consequences of potential radiological accidents. The only ESF system at the CAVALIER facility is the alternate reactivity insertion system (ARIS).

6.1 Alternate Reactivity Insertion System

In the very unlikely event that reactor systems fail so that all control rods remain in the fully withdrawn positions, the CAVALIER can be shut down with the ARIS system, which injects borated water by gravity into the moderator tank. The system is composed of a 25-gal tank of borated water connected to the CAVALIER moderator tank with a 2-in. pipe and normally closed with a manually operated valve. The ARIS system is illustrated in Figure 6.1. A leak detection trap in the tank discharge line guards against inadvertent borating of the reactor coolant.

The borated water contains boric acid and Borax in a concentration that provides 17.24 g/L of boron. If an operator opens the ARIS stop valve, sufficient solution would flow into the moderator tank in less than 1 min (~1/2 of the total) to overcome the 1.6% $\Delta k/k$ maximum excess reactivity authorized to be loaded in the reactor core. Conditions that would lead to the use of ARIS also are identified in Section 14.

6.2 Conclusion

On the basis of its review, the staff concludes that the ARIS would control the total authorized reactivity of the CAVALIER even in the unlikely event hypothesized.

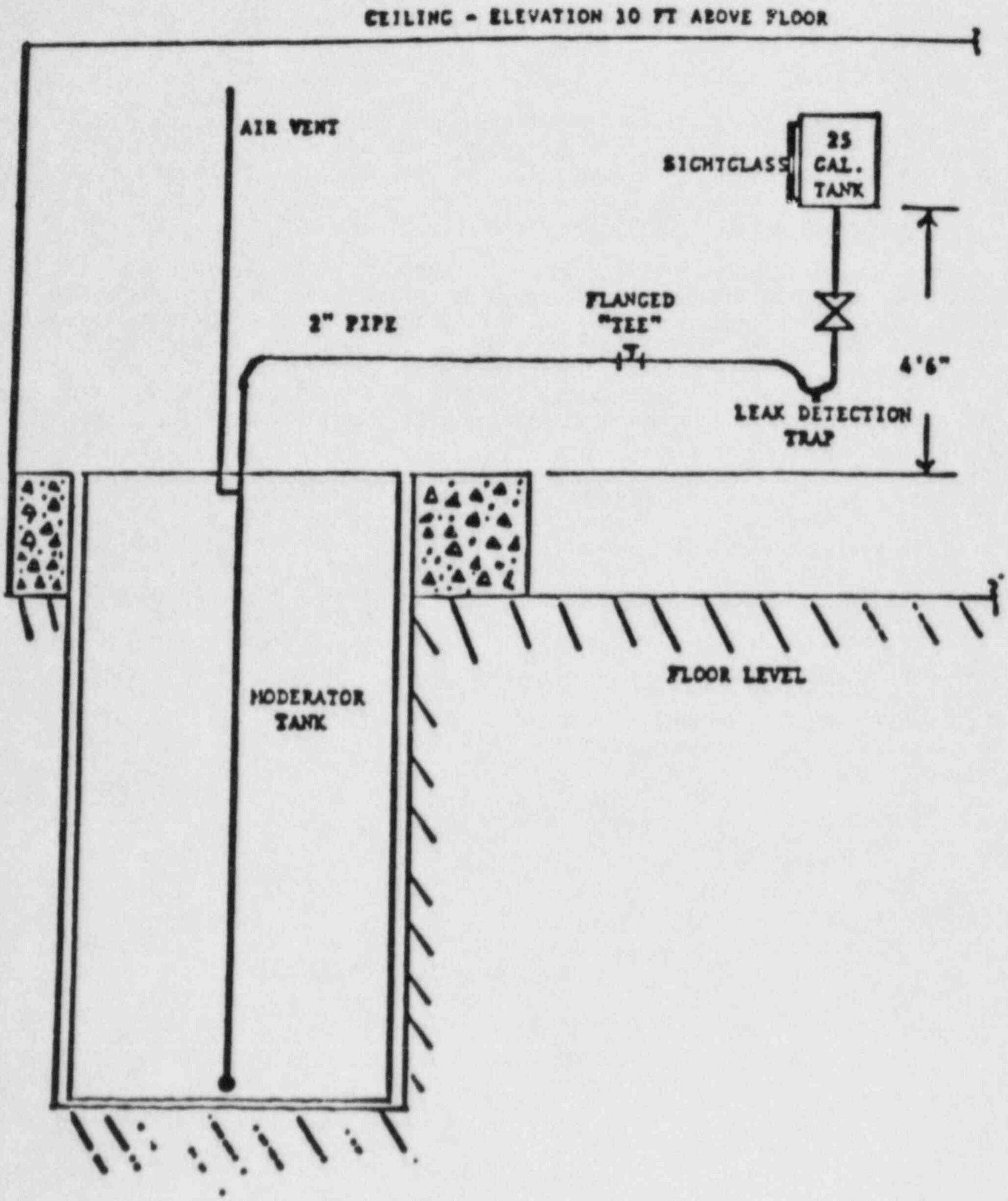

Figure 6.1 Alternate reactivity insertion system

7 CONTROL AND INSTRUMENTATION SYSTEMS

7.1 Systems Summary

The CAVALIER uses control and instrumentation systems similar in design to those on other small NRC-licensed, nonpower reactors. The operator interface components of the CAVALIER control and instrumentation systems, which include annunciators, rod controls, meters, and recorders, are located in the control console.

7.2 Reactor Control Rod Drive System

The reactor power level is controlled by four boron stainless-steel control rods connected to individual drive mechanisms. Each electromechanical control rod-drive system consists of a motor, a magnetic clutch assembly, a position-indicating device, a rack-and-pinon-drive system, and a hydraulic shock absorber. The control rod drives are activated at the reactor console by individual switches (key switch, scram switch, scram reset switch). When a scram signal is received, the electrical power to the magnetic clutch is interrupted and the rod drive units release the control rods, which insert into the core by gravity. The control rods also fall into the core and shut down the reactor in a safe manner on loss of electrical power. All four control rods may not be withdrawn simultaneously. Administrative procedures allow no more than two control rods to be simultaneously withdrawn to 10 in. (25.4 cm). Beyond this, they must be withdrawn individually.

7.3 Scram System and Interlocks

The reactor safety system provides for initiating scrams, controlling rod withdrawal, initiating interlock functions, and supplying signals to the console and annunciator panels. Figure 7.1 shows a block diagram of the CAVALIER safety system.

Scram signals from reactor instrumentation supply signals to two relay systems, each capable of scramming two control rods with a cross-connect circuit that scrams the remaining two control rods. Thus, the failure of a single component downstream of the mixer-driver will not prevent a reactor shutdown (two rods will still insert). A manual scram deenergizes all four magnetic clutches. For the CAVALIER, any two control rods will add sufficient negative reactivity to make the reactor subcritical.

The safety system is designed to initiate a reactor scram under the following conditions:

(1) high rate of change of power (period <10 s) source range BF_3 chambers
(2) high radiation at safety channels (power level)

   (a) Compensated ion chamber (log-N)
   (b) Gamma-ray ion chamber (log-G, linear power)

(3) high rate of change of power (period <10 s) log-N and log-G

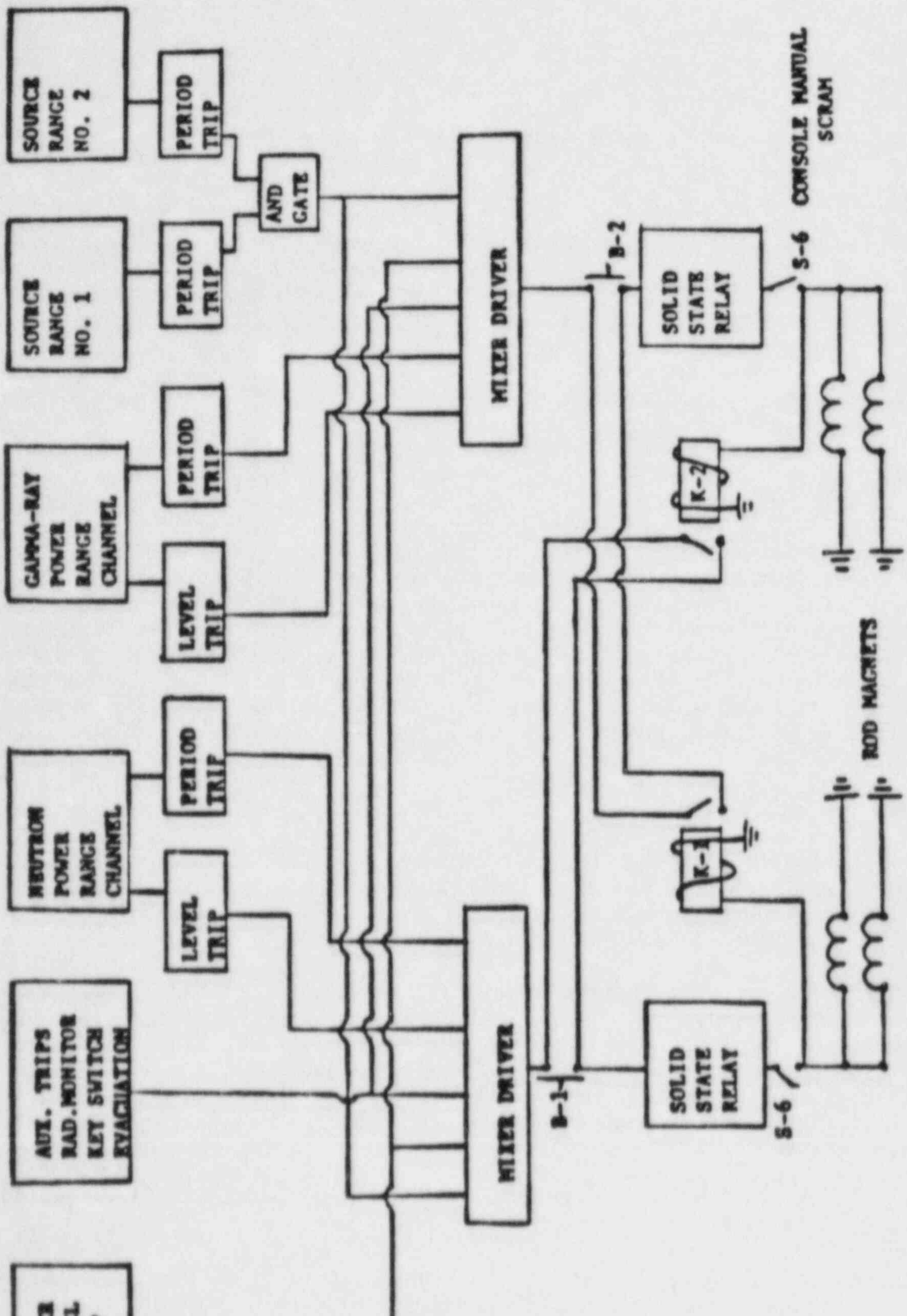

Figure 7.1 Block diagram of CAVALIER safety systems

(4) high radiation level at tank top (GM tube)
(5) low water level (float switch)
(6) loss of electrical power
(7) key switch off
(8) manual initiation
(9) initiation of evacuation alarm (from any of the following locations)

   (a) UVAR control room
   (b) first floor hallway
   (c) CAVALIER control room
   (d) UVAR experimental area

(10) initiation of fire alarm system

A rod withdrawal interlock circuit prevents reactor startup if the source strength signal is insufficient (<2 counts/s).

7.4 Instrumentation System

The reactor instrumentation system is fully integrated with the reactor safety system (rod control and scrams) to comprise a single integrated system. Both nuclear and nonnuclear parameters are measured and monitored by the system. The CAVALIER Technical Specifications require a minimum number of safety channels (listed in Table 7.1) for reactor operation. The CAVALIER instrumentation is designed to operate over two ranges of reactor power, source range and power range. Figure 7.2 provides a block diagram of the reactor safety system instrumentation.

Table 7.1 Minimum reactor safety channels

Measuring Channel	Minimum No. Operable	Function	Operating Mode in Which Required to be Operable
Tank water level monitor	1	Scram	All modes
Tank top radiation monitor	1	Scram	All modes
Startup count rates	2	To prevent control rod withdrawal when channels read <2 counts/s	Reactor startup
Reactor power level log-N (CIC)	1	Scram	All modes
Reactor power level linear gamma-ray (IC)	1	Scram	All modes
Reactor period log-N (CIC)	1	Scram at less than 5-s period	All modes

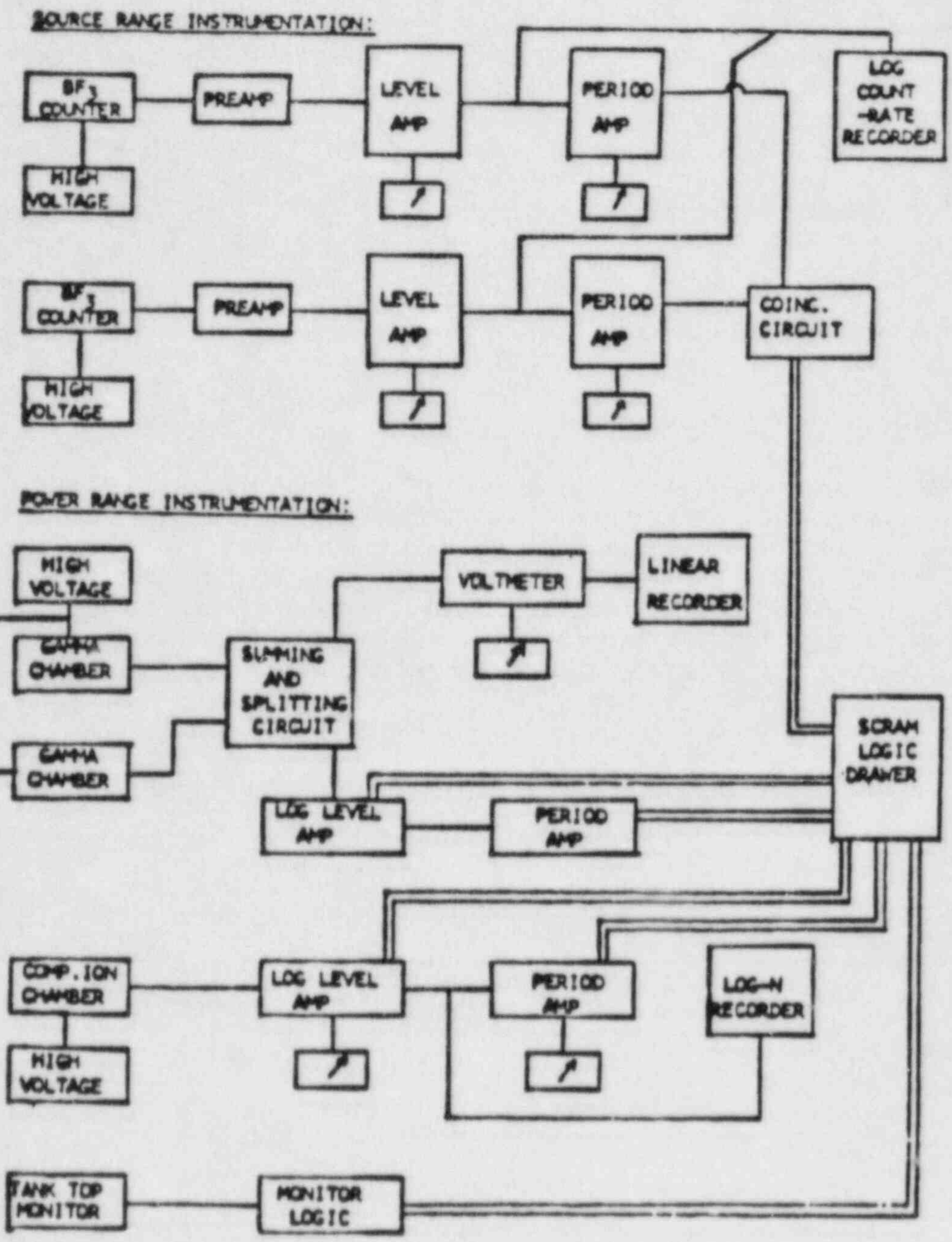

Figure 7.2 Block diagram of CAVALIER safety channels
Note: Double lines represent trip signals.

7.4.1 Neutron Monitoring Channels

The nuclear instrumentation is designed to provide the operator with the necessary information for proper manipulation of the nuclear controls. The neutron monitoring instrumentation consists of two startup channels, a log-N and period channel, and a power range and period channel. Table 7.2 gives the operating ranges and trip set points of these neutron detectors.

Table 7.2 Neutron and gamma detectors, operating ranges, and alarm and trip settings

Channel	Chamber or Detector	Ranges	Alarms and Trip Points
Startup channel 1	BF_3 detector	1 to 10^5 counts/s (1.3×10^{-5} to 1.3 W)	2 counts/s 10 s period trip (coincident with startup channel 2)
Startup channel 2	BF_3 detector	10^{-5} W to 1 W	2 counts/s 10 s (coincident with startup channel 1)
Log-N, period	Compensated ion chamber	0.03 W to 1 kW	60 W 10 s period trip
Power range (linear)	Ion chamber (gamma)	0.1 W to 1 kW	60 W
Power range (log-G), period	Ion chamber (gamma)	1 W to 10 kW	60 W 10 s period trip

All neutron detectors are sealed in aluminum cans and mounted on the perimeter of the core so that their positions can be adjusted manually for changing sensitivity and calibration.

The two startup channels, each consisting of a BF_3 detector, power supply, preamplifier, level and period amplifiers, and a log count rate meter, are identical. These channels provide for power indication from below source level (~1×10^{-5} W) to ~1 W. In addition, a minimum source-count interlock prevents rod withdrawal unless the measured neutron level exceeds a predetermined value. Also, there are coincident period trip circuits that provide for a period scram from the startup channel signals (two out of two scram circuits).

When the CAVALIER is operating in the power range, the high voltage supplied to the BF_3 detectors is turned off to prevent unnecessary deterioration of the detectors.

The log-N and period channel provides reactor period and power level indication over about seven decades (0.003 W to 1 kW) and consists of a compensated ion chamber, a power supply, a log-N amplifier/period circuit, and a log-N recorder. This channel provides for a high power scram ($\geq$60 W) and a period scram (<10 s). The linear power and log-G/period channels incorporate two gamma detecting ion chambers, a power supply, a summing and splitting circuit, a period amplifier, a voltmeter, and a linear power level recorder. These channels provide power level indication from ~1 W to ~10 kW and provide for both a linear power level scram (>60 W) and a period scram (<10 s).

7.4.2 Area Monitors

In addition to the nuclear instrumentation described above, there is a fixed-position three-channel, gamma-sensitive area monitoring system. The detectors (GM tubes) are installed above the moderator tank, in the equipment area of the reactor pit and near the control console, respectively. The monitor channels are independent units consisting of a detector, high- and low-voltage power supplies, a meter, and an alarm circuit. The monitor located above the moderator tank provides for a reactor scram and shutdown of the ventilation system in the reactor room in response to a high radiation level. The other two channels provide alarms in the event of high radiation levels. The three channels monitor radiation levels over a range of 0.01 to 1000 mR/h, with meter output displayed on the control console.

7.4.3 Water Level Channel

The water level channel consists of a float switch and relay-operated scram circuit that inputs directly into the mixer-driver and scram relays of the CAVALIER safety system. When a low water signal from the float switch is received, the relay scram circuits will release all four control rods for gravity insertion.

7.5 Conclusion

The control and instrumentation systems at the CAVALIER are well designed and provide for flexibility and reliability. There is sufficient redundancy and diversity in the major nuclear instrumentation and, in particular, the nuclear power measurements that are overlapped in the ranges of the startup, log-N, and linear power level channels. Additionally, the control system is designed to shut down the reactor automatically if electrical power is lost. The reactor scram system is designed so that a single component failure will not prevent shutdown.

From the above analysis, the staff concludes that the control and instrumentation systems at the CAVALIER comply with the requirements and performance objectives of the Technical Specifications and that they are adequate to ensure the continued safe operation of the CAVALIER.

8 ELECTRIC POWER SYSTEM

8.1 Main Power

The main electrical power to the Nuclear Engineering Building is supplied at 480 V by a commercial source through transformers located near the facility. The power is standard three-phase ac and is noise filtered. The reactor, control, and instrumentation circuits, as well as the scram-logic circuits, are protected against ac powerline fluctuations.

8.2 Emergency Backup Power

The reactor control system and the facility ventilation system are not provided with emergency backup power because the reactor automatically scrams upon loss of ac power and the decay heat generated in the core after scram will not cause fuel overheating (see Section 14). However, the security alarm system is provided with emergency battery power, and there are several standard battery-powered emergency lighting units strategically placed throughout the building for safe personnel movement.

8.3 Conclusion

On the basis of the above considerations, the staff concludes that the electrical power provisions at the CAVALIER facility provide reasonable assurance of acceptable operation and that loss of offsite power will not lead to any unsafe reactor condition.

9 AUXILIARY SYSTEMS

9.1 Fuel Handling and Storage

Fuel is rearranged in the CAVALIER core using a long, hand-held tool. Any fuel elements not in the reactor core are stored in the UVAR fresh fuel storage vault. The radioactivity level of the CAVALIER fuel is sufficiently low to preclude the necessity of handling fixtures or transfer casks to move the fuel into or out of the CAVALIER tank.

9.2 Ventilation System

The building heating and air conditioning system supplies air to the student laboratory in which the CAVALIER is located. There is no return air system because the laboratory air is forced into adjoining rooms and spaces.

The CAVALIER operating procedures require that doors to the student laboratory normally be closed during reactor operations, but they may be opened momentarily for personnel entrance or exit. Further, if a high radiation level is detected, the gamma monitor above the moderator tank trips off the supply air blower to the room and closes a damper in the air supply line, thus isolating the laboratory in the event of a radiological release.

9.3 Fire Protection System

A fire alarm system that shuts down both reactors and alarms locally and at the university police station has been installed. This system has heat sensors (one of which is located in the CAVALIER control room) and manual pull-boxes throughout the building. In addition, portable CO_2 fire extinguishers are located throughout the building, including the CAVALIER control room.

9.4 Communication System

The following means of communication are provided within the CAVALIER facility.

(1) outside telephone
(2) building loudspeaker microphone
(3) building intercommunication master station
(4) building evacuation alarm initiation button and horn

9.5 Conclusion

The auxiliary systems at the CAVALIER facility are designed and maintained adequately, and the staff concludes that they are capable of performing their intended functions to help ensure the safe cperation of the facility.

10 EXPERIMENTAL PROGRAMS

The CAVALIER serves as a source of ionizing and neutron radiation for research and radionuclide production. The primary irradiation facility is the in-pool irradiation basket. Although provisions have been made for a hydraulic or pneumatic sample transfer system, there is not such a system in place currently.

10.1 Experimental Facilities-Pool Irradiations

The open tank of the reactor permits irradiation of experiments placed in a basket that is inserted into the reactor grid plate. The placement of experiments or samples in the vicinity of the core is controlled by the reactivity effects, the mechanical stress effects, and the material content of the experiment. The limits on these factors are defined in Sections 3.2 and 3.5 of the Technical Specifications.

10.2 Experiment Review

Before any new experiment can be conducted using the CAVALIER, the experiment must be reviewed and approved by the Reactor Safety Committee. This committee is composed of at least five members, one of whom is the University Radiation Safety Officer. In addition to ensuring safe and licensed reactor use, this review and approval process allows personnel knowledgeable about radiation safety and reactor operations to consider the experiment and make recommendations for changes that might reduce personnel exposure and/or the potential of release of radioactive material to the environment. Furthermore, a licensed senior reactor operator must approve and supervise the performance of experiments, adding a direct level of control.

10.3 Conclusion

The restrictive limits placed on experiments, the low neutron flux of the reactor, and the detailed review and administrative controls for use of the reactor combine to ensure that experiments (1) are unlikely to fail, (2) are unlikely to release significant radioactivity to the environment, and (3) are unlikely to cause damage to the reactor. Therefore, the staff considers that reasonable provisions have been made so that experimental programs do not pose a significant risk of reactor damage or radiation exposure to the building occupants or the public.

11 RADIOACTIVE WASTE MANAGEMENT

Radioactive waste resulting from reactor operations is either discharged to the environment in gaseous form, released as a liquid to the holdup pond, or packaged as a solid and shipped to a licensed low-level radioactive waste burial ground.

11.1 Waste Generation and Handling Procedures

11.1.1 Solid Waste

Solid waste generated as a result of reactor operations consists primarily of ion exchange resins, potentially contaminated paper and gloves, and activated components. The amount of solid waste generated by operations of the CAVALIER has typically been small and not significant compared to the volume of waste generated by the UVAR operations. Low-level solid waste is collected and disposed of by the Radiation Safety Officer.

High-level solid radioactive waste (spent fuel) generated by routine CAVALIER operations should not be a consideration during the anticipated life of the reactor because the low level of burnup obviates the need to replace its fuel.

11.1.2 Liquid Waste

Normal reactor operations produce no radioactive liquid waste. The largest volume of potentially contaminated water would be produced by draining the CAVALIER moderator tank. Should this be necessary the water from the tank is released directly to the holdup pond. Procedure and sampling requirements control radioactivity releases from the tank to the pond. Monitoring equipment and sampling requirements ensure that release activity levels are below the maximum permissible concentrations (MPC) identified in 10 CFR 20.

11.1.3 Airborne Waste

The primary airborne (gaseous) radioactive waste component is ^{41}Ar. However, because of low neutron flux levels and limits on integrated power, ^{41}Ar levels will remain well below the limits specified in 10 CFR 20 for unrestricted areas.

11.2 Conclusion

The staff concludes that the waste management activities of the CAVALIER are conducted in a manner consistent with 10 CFR 20 and the ALARA principle (see Section 12). Because there is essentially no release of radioactive material to the environment during routine operation and releases resulting from unusual conditions are carefully controlled, there is reasonable assurance that potential doses to the public from radioactive wastes are insignificant.

12 RADIATION PROTECTION PROGRAM

The University of Virginia has a structured radiation safety program with a health physics staff equipped with radiation detection instrumentation and procedures to determine, control, and document occupational radiation exposures at its reactor facility. The reactor facility monitors liquid effluents before release. The university has developed an environmental monitoring program to verify that radiation exposures in the unrestricted areas around the reactor facility are within regulations and guidelines and to confirm the results of calculations and estimates of environmental effects resulting from the reactor program.

12.1 ALARA Commitment

The university administration has formally established the policy that all operations are to be conducted in a manner to keep all radiation exposures as low as is reasonably achievable (ALARA). This policy is implemented by a set of specific guidelines and procedures. All proposed experiments and procedures at the reactor are reviewed for ways to minimize the potential exposures of personnel. All unanticipated or unusual reactor-related exposures are investigated by both the health physics staff and the operations personnel to develop methods to prevent recurrences.

12.2 Health Physics Program

12.2.1 Health Physics Staffing

The normal full-time health physics staff at the university consists of four professionals and four technicians. One professional is located at least half-time at the reactor facility; technicians are available as needed. The onsite staff has sufficient training and experience to direct the radiation protection program for a research reactor. The health physics staff has been given the responsibility, authority, and adequate lines of communication to provide an effective radiation safety program.

12.2.2 Procedures

Written procedures have been prepared that address the health physics staff's various activities and the support that it is expected to provide to the routine operations of the university's research reactor facility. These procedures identify the interactions between the health physics staff and the operational and experimental personnel. They also specify numerous administrative limits and action points, as well as appropriate responses and corrective action if these limits or action points are reached or exceeded.

12.2.3 Instrumentation

The university has a variety of detecting and measuring instruments for monitoring potentially hazardous ionizing radiation. The instrument calibration procedures and techniques ensure that any credible type of radiation and any significant intensities will be detected promptly and measured correctly.

12.2.4 Training

All reactor-related personnel are given an indoctrination in radiation safety before they assume their work responsibilities. Additional radiation safety instructions are provided to those who will be working directly with radiation or radioactive materials. The training program is designed to orient workers and frequent visitors to restricted areas to proper health physics practices at the reactor facility. Retraining in radiation safety is provided as well. As an example, all reactor operators are given an examination annually on health physics practices and procedures. The level of retraining is determined by the examination results. The majority of the above-mentioned radiation safety training is provided by the health physics staff.

12.3 Radiation Sources

12.3.1 Reactor

Radiation from the reactor core is the primary source of radiation directly related to reactor operations.

The fission products are contained in the aluminum cladding of the fuel, and radiation exposure rates from the reactor core are reduced to acceptable levels by water and concrete biological shielding. The ion exchange resin is changed routinely before high levels of radioactive materials have accumulated, thereby limiting personnel exposure.

12.3.2 Extraneous Sources

Sources of radiation that may be considered as incidental to normal reactor operation, but associated with reactor use, include radioactive isotopes produced for research, activated components of experiments, and activated samples or specimens. A small, sealed plutonium-beryllium neutron source is authorized by the reactor license to be used in connection with reactor operations.

Personnel exposure to radiation from intentionally produced radioactive material as well as from the required manipulation of activated experimental components, is controlled by rigidly developed and reviewed operating procedures that use the normal protective measures of time, distance, and shielding.

The Nuclear Engineering Department also operates a 2-MW reactor (UVAR) in the same building as the CAVALIER; it is at the other end of the building, and its operation is governed by an independent NRC license. During normal operations, the UVAR contributes no radiation exposure to personnel in the CAVALIER area.

12.4 Routine Monitoring

12.4.1 Fixed-Position Monitors

The CAVALIER has several fixed-position radiation monitors that have adjustable alarm set points and read out at the control console (see Section 7.4.2).

12.4.2 Experimental Support

The health physics staff participates in experiment planning by reviewing all proposed procedures for methods of minimizing personnel exposures and limiting the generation of radioactive waste. Approved procedures specify the type and degree of health physics involvement in each activity. As examples, standard operating procedures require that changes in experimental setups include a survey by health physics staff using portable instrumentation, and all items removed from the reactor room or experimental room must be surveyed and tagged by knowledgeable personnel.

12.5 Occupational Radiation Exposures

12.5.1 Personnel Monitoring Program

Personnel exposures are measured by the use of film badges assigned to individuals who might be exposed to radiation. In addition, self-reading dosimeters are used, and instrument dose rate and time measurements are used to administratively keep occupational exposures below the applicable guidelines specified in 10 CFR 20.

All visitors are provided self-reading dosimeters for monitoring purposes.

12.5.2 Personnel Exposures

Facility, staff, students and frequent visitors to the facility are monitored with film badges; a 5-year history of exposures is shown in Table 12.1. The highest exposures have been to the staff members who also are directly involved in the operation of the UVAR. The maximum whole-body exposure of any individual in 1983 was 620 mrem. Because the UVAR and the CAVALIER have the same staff and use one personnel dosimetry system, it is not possible to determine how much of the "facility" dose is a result of CAVALIER operation. However, the licensee estimated that the CAVALIER contribution to the exposure history is <1% of the total shown in Table 12.1, which the staff concludes indicates acceptable performance on the parts of both management and users of the two reactors.

Table 12.1 History of personnel radiation exposure at the University of Virginia reactor facilities

Whole Body Exposure Range (Rems)	Number of Individuals in Each Range				
	1980	1981	1982	1983	1984*
No measureable exposure	73	44	60	45	33
Measureable exposure < 0.1	46	52	44	54	56
0.1 to 0.25	0	4	12	3	4
0.25 to 0.5	0	3	3	2	5
0.50 to 0.75	0	0	0	0	0
0.75 to 1.0	0	0	0	0	0
>1.0	0	0	0	0	0

*As of November 1984.

12.6 Effluent Monitoring

12.6.1 Airborne Effluents

As discussed in Section 11, airborne (gaseous) radioactive effluents from the reactor facility are minimal. Conservative calculations, based on maximum reactor use, show that less than 1 mCi of ^{41}Ar would be discharged annually, at a concentration well below the maximum permissible by 10 CFR 20, Appendix B.

12.6.2 Liquid Effluents

The reactor does not generate radioactive liquid waste during routine operation. Because the demineralizer is nonregenerable, the only liquid waste released from the system would be as a result of overfilling or draining the moderator tank. This potentially radioactive liquid would be released directly to the pond that is within the site perimeter fence. Before the contents of the pond are released, samples are collected and analyzed to confirm the actual concentration of radioactivity. Releases to the pond from the CAVALIER have been below the applicable MPC of 10 CFR 20, Appendix B.

Experimental activities associated with reactor usage may generate radioactive liquids. These liquids are collected and disposed of by the Radiation Safety Officer in accordance with applicable regulations.

12.7 Environmental Monitoring

The environmental monitoring program consists of air particulate and water samples collected at the reactor site and at two locations within the City of Charlottesville.

12.8 Potential Dose Assessments

Natural background radiation levels in the Charlottesville area result in an average exposure of about 80 mrem/yr (0.8 mSv/yr) to each individual residing there. At least an additional 10% [~8mrem/yr (0.08 mSv/yr)] will be received by those living in a brick or masonary structure. Any medical diagnostic exposures will add to the natural background radiations, increasing the total cumulative annual exposure of those individuals.

On the basis of normal reactor use, the maximum potential offsite dose resulting from ^{41}Ar would be much less than 1 mrem per year, so there should be no significant contribution to the background radiation levels in unrestricted areas from the CAVALIER.

12.9 Conclusions

The staff concludes that appropriate procedural and administrative controls and lines of communication between the CAVALIER operations personnel and the health physics staff exist to enable an adequate radiation protection program. The environmental monitoring program, the occupational radiation monitoring program, and the personnel dosimetry system are sufficient to determine and ensure the effectiveness of the radiation protection program. The adequacy of the radiation protection program at the CAVALIER is verified by the history of low personnel exposures and negligible releases of radioactive material to the environment.

Because the health and safety of the staff and public are protected adequately, and because the facility has operated and is expected to continue to operate within the guidelines of 10 CFR 20 and is committed to the ALARA philosophy, the staff concludes that the radiation protection program is acceptable.

13 CONDUCT OF OPERATIONS

13.1 Overall Organization

Responsibility for the safe operation of the reactor facility is vested within the chain of command shown in Figure 13.1. The Reactor Director is delegated responsibility for overall facility operation.

13.2 Training

Most of the training of reactor operators is done by in-house personnel. The licensee's Operator Requalification Program has been reviewed, and the staff concludes that it meets the applicable regulations (10 CFR 50.54(i-1) and Appendix A of 10 CFR 55) and is consistent with the guidance of ANS 15.4.

13.3 Emergency Planning

10 CFR 50.54(q) and (r) require that a licensee authorized to possess and/or operate a research reactor shall follow and maintain in effect an emergency plan that meets the requirements of Appendix E of 10 CFR 50. In accordance with regulations, by letter dated August 27, 1982, the licensee submitted an Emergency Plan following the existing guidance (RG 2.6, Rev. 1, March 1982; ANSI/ANS 15.16, 1981 Draft). By letter dated October 3, 1984, the NRC transmitted its approval of the Emergency Plan to the licensee.

13.4 Operational Review and Audits

The Reactor Safety Committee (RSC) provides independent review and audit of facility activities. The Technical Specifications outline the qualifications and provide that alternate members may be appointed by the Chairman. The RSC must review and approve plans for modifications to the reactor, new experiments, and proposed changes to the license or to procedures. The RSC also is responsible for conducting audits of reactor facility operations and management and for reporting the results thereof to the Chancellor of the University of Virginia.

13.5 Physical Security Plan

The UVA facility has established and maintains a program to protect the reactors and their fuel and to ensure their security. The NRC staff has reviewed the Physical Security Plan and concludes that the plan, as amended, meets the requirements of 10 CFR 73.67 for special nuclear material of moderate strategic significance. The UVA facility's inventory of special nuclear material for operation of both reactors falls within that category.

Both the Physical Security Plan and the staff's evaluation are withheld from public disclosure under 10 CFR 2.790(d)(1). Amendment No. 2 to the facility Operating License R-123 dated August 25, 1981, incorporated the Physical Security Plan as a condition of the license.

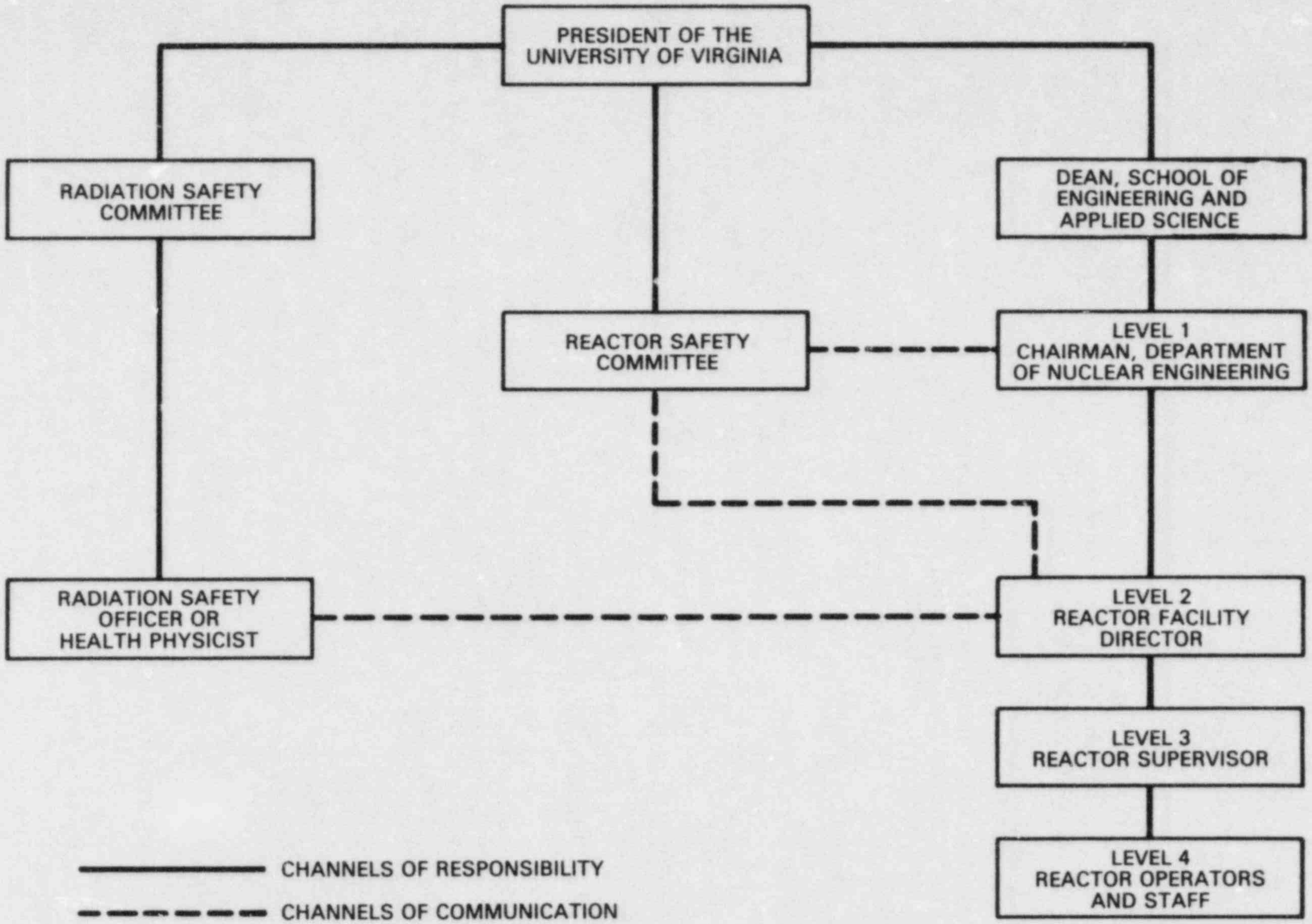

Figure 13.1 Organization of the reactor facility at the University of Virginia

13.6 Conclusion

On the basis of the above discussions, the staff concludes that the licensee has sufficient experience, management structure, and procedures to provide reasonable assurance that the CAVALIER will be managed in a way that will cause no significant risk to the health and safety of the public.

14 ACCIDENT ANALYSIS

In establishing the safety of the CAVALIER operation, the licensee analyzed a spectrum of accidents to ensure that these events would not result in potential hazards to the reactor staff or the public. In addition, the staff has evaluated the licensee's submitted documentation and analysis of potential accidents and their possible consequences to the operating staff and to the public.

The following potential accidents and their consequences were considered by the staff to be sufficiently credible for evaluation and analysis.

(1) failure of a fueled experiment
(2) step reactivity insertion (step nuclear excursion)
(3) ramp reactivity insertion (ramp nuclear excursion)
(4) loss of moderator tank water
(5) fuel handling accident

Of these potential credible accidents, the staff concluded that the only one with the potential for releasing radioactive material to the CAVALIER room and to the unrestricted area outside the reactor facility is the failure of a fueled experiment (one containing fissile material intended for neutron irradiation) and the subsequent release of fission products into the reactor room. None of the reactor transients or other accidents analyzed for the CAVALIER posed a potential risk of fuel cladding failure and therefore would not result in release of any radioactive material.

14.1 <u>Failure of a Fueled Experiment</u>

The staff has designated failure of a fueled experiment as the maximum hypothetical accident (MHA) for the CAVALIER. The CAVALIER Technical Specifications allow fueled experiments generating less than 1 W (3.2×10^{10} fissions/s) thermal power. The staff did not try to develop or justify a specific scenario of how the accident might occur nor to evaluate the probability of its occurrence. Instead, the staff assumed that a fueled experiment does fail in such a manner that it releases to the reactor room a conservatively large fraction of the fission products that have accumulated and considered the potential consequences of this accident.

14.1.1 Assumptions

Because the Technical Specifications do not limit the fuel form in an experiment, it was conservatively assumed that 100% of the noble gases, 50% of the halogens, and 1% of the solid (^{90}Sr) fission product inventory is released when total failure of the experiment occurs (AEC TID-14844 and NUREG-0772 and NUREG-0928). For the relatively short-lived isotopes of Kr, I, and Xe it was assumed that the sample had been irradiated at 1 W for sufficient time just before failure to establish equilibrium levels of the radionuclides. For the long-lived ^{90}Sr, integrated irradiation of 1 W-year was assumed. These irradiation conditions represent conservatively high levels for the CAVALIER facility, so all calculated doses correspondingly will be conservatively high.

Additionally, it was assumed that the fisson products were released instantaneously into the room, with absorption of 50% of the iodines in the pool water, and dispersed uniformly within the air. It was further assumed that a person inside the room was exposed to the airborne radioactivity for 10 min before being alerted and evacuated from the room. The free air volume of the reactor room is ~184 m^3 and for evaluating the inhalation volumes, a breathing rate of 3.47×10^{-4} m^3/s was assumed.

Calculations of potential whole-body doses outside the building unrealistically but conservatively assumed immersion in a semi-infinite cloud (see NUREG-0851 for more realistic finite cloud doses). For the occupational doses, it was assumed that the ventilation system was shut down and all of the released fission products remained in the reactor room. For the doses to the public just outside the building, it was assumed that all of the contaminated air would leak from the building at a constant rate during a 2-hour time interval, with no decrease in source strength because of radioactive decay. It also was assumed conservatively that the exposure to a person outside the building extends over the entire 2-hour leakage time. A short-term transport dilution factor of 10^{-2} s/m^3 was assumed even though the building is surrounded by an exclusion fence outside of which dilution would be much larger. The calculated doses for the above conservative assumptions and locations are presented in Table 14.1.

Table 14.1 Doses resulting from postulated failure of a fueled experiment

Dose and Location	Whole Body Immersion Dose	Thyroid Committed Dose
10-min occupational dose in reactor room	8 mrem (8×10^{-2}mSv)	12 rem (0.12 Sv)
2-h public dose immediately outside the reactor building	1.76 mrem (1.76×10^{-2} mSv)	35 mrem (0.35 mSv)
		Skeletal Committed Dose
Sr^{90} 10-min occupational dose in the reactor room		18 mrem (18×10^{-2}mSv)
2-h public dose immediately outside the reactor building		0.11 mrem (0.11×10^{-2}mSv)

The licensee has also analyzed the consequences of the failure of a fueled experiment, using slightly different assumptions from those used by the staff, and has calculated the maximum potential committed thyroid doses resulting from inhalation of airborne iodine radionuclides (considered to be the critical fission product). The resulting consequences, although more realistic and less conservative than those calculated by the staff, are in reasonable agreement with those of Table 14.1. In both cases, the resulting potential doses are well below the guidelines of 10 CFR 20.

14.1.2 Assessment

Because there is no credible way that the above postulated MHA could occur without operating personnel being alerted immediately, orderly evacuation of the reactor room would be accomplished within minutes. As a result of the assumptions used, the calculated occupational and public doses shown in Table 14.1 are significantly higher than could occur realistically. On the basis of the above discussions, the staff concludes that any fueled experiments can be performed at the CAVALIER facility in accordance with the limitations imposed by the Technical Specifications without undue risk to the health and safety of the operating staff or the public. The staff concludes also that the MHA for this reactor would not cause unacceptable radiation exposure of the public. The analysis shows that even if a conservatively high fission product release were assumed, doses to occupational personnel and to the public in unrestricted areas would be below the guideline values for 10 CFR 20.

14.2 Step Reactivity Insertion

The licensee has postulated a step reactivity insertion (nuclear excursion) in which all of the authorized excess reactivity is inserted into the core instantaneously. The staff has not been able to identify a credible method for instantaneously inserting all of the available excess reactivity (1.6% $\Delta k/k$); however, it is assumed for purposes of the analysis that it does occur. The reactor is assumed to be operating at a power level between 0 and 100 W when all of the available excess reactivity is inserted rapidly into the core. The potential significant consequences associated with the rapid insertion of reactivity accident are damage to the fuel or cladding material and/or direct radiation exposure to operations personnel.

Tests conducted by the predecessors of the Idaho National Engineering Laboratory on the SPERT-I (Miller, 1964; Edlund, 1957; Nyer, 1956) reactor containing fuel elements similar to those in CAVALIER indicate that instantaneous 1.6% $\Delta k/k$ reactivity addition produces approximately a 10 MW·s energy release. The SPERT tests demonstrated that no fuel melting or fission product release occurred under these conditions.

Therefore, the staff concludes that the postulated step reactivity insertion accident would not pose a significant radiological risk to the environment or the public. The staff also concurs with the licensee's calculations that the maximum integral dose resulting from a 10 MW·s pulse would be ~600 mR at the top of the water-filled tank. However, this is a restricted area, and potential maximum exposures in the unrestricted areas would be much lower and well within 10 CFR 20 guidelines.

Although the step reactivity excursion described above would not result in a release of fission product radioactivity, the licensee, for calculational purposes, has hypothesized that such a release occurs following a 10 MW·s transient and has analyzed the consequences. The staff reviewed the analysis and found that the methods were applied suitably. However, because no credible step insertion of reactivity will result in the release of fission product activity, the staff considers that such an accident need not be evaluated further.

14.3 Ramp Reactivity Insertion

The licensee has analyzed the potential power transient resulting from the ramp withdrawal of the control rods. Two reactivity insertion rates were considered, 1×10^{-4} $\Delta k/k/s$ and 2×10^{-4} $\Delta k/k/s$. The first corresponds to withdrawal of one rod, and the second corresponds to a conservative rate resulting from the simultaneous withdrawal of two rods. The analysis assumed that the reactor was operating at an initial power level of 100 W when the ramp insertions began. For these insertions, it was conservatively assumed that the scram functions of the power channels failed, but that the reactor period would still activate the scram circuitry and terminate the transients. It was shown that for the smaller ramp, the power level reached 2200 W (corresponding to a total energy release of 0.02 MW·s) before the transient was terminated by the 5-s period scram. For the higher ramp insertion, the reactor scrammed on the 5-s period when the power level reached ~550 W, corresponding to a total energy release of 0.004 MW·s. The analysis indicated that the power increase was turned around as soon as the rods began to insert. In neither case did the rise in fuel temperatures exceed 1°C. The integral doses at the top of the moderator tank were calculated for each case and the results were: 1.1 mrem for the 1×10^{-4} $\Delta k/k/s$ ramp insertion and 0.22 mrem for the 2×10^{-4} $\Delta k/k/s$ ramp. The staff has reviewed the licensee's assumptions and calculations and finds them reasonable and appropriate. The staff concludes that there is no credible ramp reactivity insertion that could result in fuel damage, or a release of radioactivity to the environment or significant direct radiation exposures to the reactor personnel or the public.

14.4 Loss of Moderator Tank Water

The loss of moderator tank water was postulated for the CAVALIER, and resulting dose rates were calculated. The licensee assumed loss of moderator tank water resulting from the rupture of the drain line located at the bottom of the reactor tank. The licensee further assumed the proper operation of a low water level scram. No credit was taken for air shielding or self-shielding from the fuel elements themselves, nor for any shielding by the floor laboratory located above the reactor.

Because of the concrete block shield wall surrounding the moderator tank, the staff has not been able to identify a credible method for an instantaneous total loss of the moderator tank water. Therefore, it was assumed that the 2-in (5.08-cm) pipe leading from the moderator tank to the cleanup deionizer broke, draining the moderator tank. The calculated time required to drain the moderator tank to the bottom of the fuel would be ~20 min.

The doses resulting from the accident were calculated for two cases. Case I assumed the reactor was operating at a power level of 100 W for 1 hour before the accident, and Case II assumed a 10-W operation for 100 hour before the accident.

The dose rates at the top of the reactor tank, ~20 min after the reactor is shut down were calculated to be 6.4 R/h for Case I and ~1.5 R/h for Case II. The dose rates at the floor of the student laboratory were 1.02 R/h for Case I and 0.24 R/h for Case II. The radiation field would be collimated because of the reactor shield wall, thus allowing the operator to take corrective actions without excessive radiation exposure. There also would be sufficient time to evacuate the student laboratory, thus limiting the exposure to those occupants.

In the case of a loss of moderator-coolant accident, the reactor core would be cooled principally by natural convection airflow. The analysis indicated that, if the pool water were emptied in ~20 min, the resulting residual decay power from an hour of operation at 100 W is ~0.54 W. For the second case, where the reactor is operated for 100 hour at ~10 W, the resulting residual decay power would be ~0.15 W. These powers would result in insignificant fuel temperature increases.

On the basis of above analysis, the staff concludes that the decay heat resulting from a loss of moderator tank water can be dissipated readily by the natural convection airflow in the moderator tank and no fuel damage would result. It is further concluded that the time needed to drain the tank (~20 min) will allow for mitigating action from the reactor operator, and the direct radiation dose resulting from the loss of water will not pose a significant threat to the health and safety of the public or the building occupants.

14.5 Fuel Handling Accident

The operating limits imposed on the CAVALIER preclude the use of any fuel that has been significantly irradiated. Only unirradiated fuel or fuel with extremely low burnup is used in the CAVALIER core. Therefore, there is no significant fission product inventory to pose any hazards from the handling of the CAVALIER fuel. Even if the cladding of the fuel were to be breached accidentally, there would be no significant radiation hazard to the staff or to the general public.

14.6 Conclusion

The staff has reviewed the credible accidents for the CAVALIER facility. On the basis of its review, the postulated accident with the greatest potential effect on the public and operating personnel is the total failure of a fueled experiment. The analysis of this accident has shown that even if this unlikely event should occur and result in a conservatively high fission product release, the resulting exposures to a person within the affected area and to a person immediately outside the building in the unrestricted areas would still be below the guidelines of 10 CFR 20. Therefore, the staff concludes that the operating systems of the facility, together with the Technical Specifications limitations, provide reasonable assurance that the CAVALIER can continue to be operated with no significant risk to the health and safety of the public resulting from accidents.

15 TECHNICAL SPECIFICATIONS

The licensee's Technical Specifications evaluated in this licensing action define certain features, characteristics, and conditions governing the continued operation of this facility. These Technical Specifications are explicitly included in the renewal license as Appendix A. Formats and contents acceptable to the NRC have been used in the development of these Technical Specifications, and the staff has reviewed them using ANS 15.1, "The Development of Technical Specifications for Research Reactors" as a guide. Accordingly, these Technical Specifications may contain changes from the previously approved set. The licensee has either requested or concurred in these changes.

On the basis of its review, the staff concludes that normal operation of the CAVALIER within the limits of the Technical Specifications will not result in offsite radiation exposures in excess of the guidelines of 10 CFR 20. Furthermore, the limiting conditions for operation and surveillance requirements will limit the likelihood of malfunctions and mitigate the consequences to the public of off-normal or accident events.

16 FINANCIAL QUALIFICATIONS

The CAVALIER is operated by the University of Virginia, an agency of the State of Virginia, in support of its assigned educational and research mission. Therefore, the staff concludes that funds will be made available as necessary to support continued operations, and eventually to shut down the facility and maintain it in a condition that would constitute no risk to the public. The applicant's financial status was reviewed and found to be acceptable in accordance with the requirements of 10 CFR 50.33(f).

17 OTHER LICENSE CONSIDERATIONS

17.1 Prior Reactor Utilization

Previous sections of this SER concluded that normal operation of the reactor causes insignificant risk of radiation exposure to the public and that only an off-normal or accident event could cause some measurable exposure. However, even the maximum hypothetical accident would not lead to a dose to the most exposed individual greater than applicable guideline values of 10 CFR 20.

The staff concluded that the reactor was initially designed and constructed to operate safely. The staff also considered for this review whether prior operation would cause significant degradation in the capability of components and systems to perform their safety function. Because fuel cladding is the primary barrier to release of fission products to the environment, possible mechanisms that could lead to detrimental changes in cladding integrity were considered. Prominent among the considerations were the following: (1) radiation degradation of cladding integrity, (2) high fuel temperature or temperature cycling leading to changes in the mechanical properties of the cladding, (3) corrosion or erosion of the cladding leading to thinning or other weakening, (4) mechanical damage resulting from handling or experimental use, and (5) degradation of safety components or systems.

The staff's conclusions regarding these parameters, in the order in which they were identified above, are as follows:

(1) Nearly identical fuel has been laboratory tested elsewhere and has been exposed under similar irradiation conditions to much higher total radiation doses in operating reactors, such as at the Oak Ridge Research Reactor and the Omega West Reactor (Los Alamos National Laboratory). No significant degradation of cladding has resulted.

(2) The power density, coolant convective flow rates, and maximum temperatures reached in the CAVALIER core are far below similar parameters in some other nonpower reactors using similar fuel. No fuel damage has occurred during normal operations in these other reactors.

(3) The coolant flow rate at CAVALIER is essentially zero; and much lower than used at several higher powered research reactors using MTR-type fuel. No cladding erosion problems have been observed at these other reactors. At CAVALIER corrosion is kept to a reasonable minimum by careful control of the conductivity of the primary coolant water.

(4) The fuel is handled as infrequently as possible, consistent with required use. Any indications of possible damage or degradation are investigated immediately, and damaged fuel would be removed from service, in accordance with Technical Specifications. All experiments placed near the core are isolated from the fuel cladding by a water gap and at least one barrier or encapsulation.

(5) UVA performs regular preventive and corrective maintenance and replaces components, as necessary. Nevertheless, there have been some malfunctions of equipment. However, the staff review indicates that most of these malfunctions have been random, one-of-a-kind incidents, typical of even good quality electromechanical instrumentation. There is no indication of significant degradation of the instrumentation, and the staff further has determined that the preventive maintenance program would lead to adequate identification and replacement before significant degradation occurred. Therefore, the staff concludes that there has been no apparent significant degradation of safety equipment and, because there is strong evidence that any future degradation will lead to prompt remedial action by UVA, there is reasonable assurance that there will be no significant increase in the likelihood of occurrence of a reactor accident as a result of component aging.

17.2 Conclusion

In addition to the considerations above, the staff has reviewed annual reports and event reports from the licensee and inspection reports and informal comments from the regional office. On the basis of this review, the staff concludes that there has been no significant degradation of equipment and that facility management will continue to maintain and operate the reactor so that there is no significant increase in the radiological risk to the employees or the public.

18 CONCLUSIONS

On the basis of its evaluation of the application as set forth above, the staff has determined that

(1) The application for renewal of Operating License R-123 for CAVALIER filed by the University of Virginia, dated June 22, 1984, as supplemented, complies with the requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's regulations set forth in 10 CFR, Chapter I.

(2) The facility will operate in conformity with the application as supplemented; the provisions of the Act, and the rules and regulations of the Commission.

(3) There is reasonable assurance (a) that the activities authorized by the operating license can be conducted without endangering the health and safety of the public, and (b) that such activities will be conducted in compliance with the regulations of the Commission set forth in 10 CFR, Chapter I.

(4) The licensee is technically and financially qualified to engage in the activities authorized by the license in accordance with the regulations of the Commission set forth in 10 CFR, Chapter I.

(5) The renewal of this license will not be inimical to the common defense and security or to the health and safety of the public.

19 REFERENCES

American National Standards Institute/American Nuclear Society (ANSI/ANS) 15 Series.

American Nuclear Society (ANS) 15.1, "Standard for the Development of Technical Specifications for Research Reactors," 1982.

---, ANS 15.4, "Selection and Training of Personnel for Research Reactors," 1977.

---, ANS 15.16, "Standard for Emergency Planning for Research Reactors," 1981 Draft.

Code of Federal Regulations, Title 10, "Energy," U.S. Government Printing Office, Washington, D.C.

Edlund, M. C., L. C. Noderer, "Analysis of Borax Experiments and Application to Safety Analysis of Research Reactors," U.S. Atomic Energy Commission, Report CF-57-7-92, 1957.

Miller, R. W., et al., "Report of the SPERT I Destructive Test Program on an Aluminum, Plate-Type, Water-Moderated Reactor," IDO-16883, June 1964.

Nyer, W. E., S. G. Forbes, F. L. Bentzen, G. O. Bright, F. Schroder, and T. R. Wilson, "Experimental Investigations of Reactor Transients," Idaho Operations Office, Report IDO 16285, April 20, 1956.

U.S. Atomic Energy Commission (AEC), TID-14844, "Calculation of Distance Factors for Power and Test Reactor Sites," DiNunno, J. J. et al., March 23, 1962.

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13. ABSTRACT (200 words or less)

This Safety Evaluation Report for the application filed by the University of Virginia for a renewal of operating license number R-123 to continue to operate a training and research reactor (CAVALIER) has been prepared by the Office of Nuclear Reactor Regulation of the U.S. Nuclear Regulatory Commission. The facility is owned and operated by the University of Virginia and is located on the campus in Charlottesville, Virginia. Based on its technical review, the staff concludes that the reactor facility can continue to be operated by the university without endangering the health and safety of the public or endangering the environment.

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