UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

ENVIRONMENTAL ASSESSMENT

RESEARCH AND TRAINING REACTOR

UNIVERSITY OF VIRGINIA

DOCKET NO. 50-396

Description of Proposed Action

This Environmental Assessment is written in connection with the proposed renewal of the operating license for the University of Virginia CAVALIER training reactor at Charlottesville, Virginia, in response to a timely application from the licensee dated June 22, 1984, as supplemented. The proposed action would authorize continued operation of the reactor in the manner that it has been operated since facility Operating License No. R-123 was issued in 1974. Currently, there are no plans to change any of the structures or operating characteristics associated with the reactor during the renewal period requested by the licensee.

Need for the Proposed Action

The operating license for the facility expired on July 30, 1984. The licensee made a timely request for renewal. The proposed action is required to authorize continued operation so that the facility can continue to be used in the licensee's mission of training and research.

Alternatives to the Proposed Action

The only reasonable alternative to the proposed action that was considered was not renewing the operating license. This alternative would have led to cessation of operations, with a resulting change in status and a likely small impact on the environment.

Environmental Impact of Continued Operation

The CAVALIER operates in an existing shielded water tank inside an existing building, so this licensing would lead to no change in the physical environment.

Based on the review of the specific facility operating characteristics that are considered for potential impact on the environment, as set forth in the staff's Safety Evaluation Report (SER)[1], for this action, it is concluded that renewal of this operating license will have an insignificant environmental impact. Although judged insignificant, operating features with the greatest potential environmental impact are summarized below.

Argon-41, a product from neutron irradiation of air during operation, is the principal airborne radioactive effluent from the CAVALIER during routine operations. Conservative calculations by the staff, based on the total amount of Ar-41 released from the reactor during a year, predict a maximum potential annual whole body dose of less than 1 millirem in unrestricted areas. Radiation exposures measured outside of the reactor facility building are consistent with this computation.

The staff has considered hypothetical credible accidents at CAVALIER and has concluded that there is reasonable assurance that such accidents will not release a significant quantity of fission products from the fuel cladding or fueled experiments and, therefore, will not cause significant radiological hazard to the environment or the public.

This conclusion is based on the following:

a) the excess reactivity available under the technical specifications is insufficient to support a reactor transient generating enough energy to cause overheating of the fuel or loss of integrity of the cladding,

b) even after prolonged operation at a power level of 100 watts, the inventory of fission products in the fuel cannot generate sufficient radioactive decay heat to cause fuel damage even in the hypothetical event of instantaneous total loss of coolant, and

c) the hypothetical loss of integrity of a fueled experiment will not lead to radiation exposures in the unrestricted environment that exceed the guideline values of 10 CFR 20.

In addition to the analyses in the SER summarized above, the environmental impact associated with operation of research reactors has been generically evaluated by the staff and is discussed in the attached generic evaluation. This evaluation concludes that there will be no significant environmental impact associated with the operation of research reactors licensed to operate at power levels up to and including 2 MWt and that an Environmental Impact Statement is not required for the issuance of construction permits or operating licenses for such facilities. We have determined that this generic evaluation is applicable to operation of the CAVALIER and that there are no special or unique features that would preclude reliance on the generic evaluation.

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[1] NUREG-1119, "Safety Evaluation Report Related to the Renewal of the Operating License for the CAVALIER Training Reactor at the University of Virginia."

Agencies and Persons Consulted

The staff has obtained the technical assistance of the Los Alamos National Laboratory in performing the safety evaluation of continued operation of the University of Virginia CAVALIER facility.

Conclusion and Basis for Finding of No Significant Environmental Impact

Based on the foregoing considerations, the staff has concluded that there will be no significant environmental impact attributable to this proposed license renewal. Having reached this conclusion, the staff has further concluded that no Environmental Impact Statement for the proposed action need be prepared and that a Finding of No Significant Environmental Impact is appropriate.

Dated: May 1, 1985

ENVIRONMENTAL CONSIDERATIONS REGARDING THE LICENSING OF

RESEARCH REACTORS AND CRITICAL FACILITIES

Introduction

This discussion deals with research reactors and critical facilities which are designed to operate at low power levels, 2 MWt and lower, and are used primarily for basic research in neutron physics, neutron radiography, isotope production, experiments associated with nuclear engineering, training and as a part of a nuclear physics curriculum. Operation of such facilities will generally not exceed a 5-day week, 8-hour day, or about 2000 hours per year. Such reactors are located adjacent to technical service support facilities with convenient access for students and faculty.

Sited most frequently on the campuses of large universities, the reactors are usually housed in already existing structures, appropriately modified, or placed in new buildings that are designed and constructed to blend in with existing facilities. However, the environmental considerations discussed herein are not limited to those which are part of universities.

Facility

There are no exterior conduits, pipelines, electrical or mechanical structures or transmission lines attached to or adjacent to the facility other than for utility services, which are similar to those required in other similar facilities, specifically laboratories. Heat dissipation is generally accomplished by use of a cooling tower located on the roof of the building. These cooling towers typically are on the order of 10' x 10' x 10' and are comparable to cooling towers associated with the air-conditioning systems of large office buildings.

Make-up for the cooling system is readily available and usually obtained from the local water supply. Radioactive gaseous effluents are limited to Ar-41 and the release of radioactive liquid effluents can be carefully monitored and controlled. Liquid wastes are collected in storage tanks to allow for decay and monitoring prior to dilution and release to the sanitary sewer system. Solid radioactive wastes are packaged and shipped offsite for storage at NRC-approved sites. The transportation of such waste is done in accordance with existing NRC-DOT regulations in approved shipping containers.

Chemical and sanitary waste systems are similar to those existing at other similar laboratories and buildings.

Environmental Effects of Site Preparation and Facility Construction

Construction of such facilities invariably occurs in areas that have already been disturbed by other building construction and, in some cases, solely within an already existing building. Therefore, construction would not be expected to have any significant effect on the terrain, vegetation, wildlife or nearby waters or aquatic life. The societal, economic and esthetic impacts of construction would be no greater than those associated with the construction of a large office building or similar research facility.

Environmental Effects of Facility Operation

Release of thermal effluents from a reactor of less that 2 MWt will not have a significant effect on the environment. This small amount of waste heat is generally rejected to the atmosphere by means of small cooling towers. Extensive drift and/or fog will not occur at this low power level.

Release of routine gaseous effluents can be limited to Ar-41, which is generated by neutron activation of air. Even this will be kept as low as practicable by using gases other than air for supporting experiments. Yearly doses to unrestricted areas will be at or below established guidelines in 10 CFR 20 limits. Routine releases of radioactive liquid effluents can be carefully monitored and controlled in a manner that will ensure compliance with current standards. Solid radioactive wastes will be shipped to an authorized disposal site in approved containers. These wastes should not require more than a few shipping containers a year.

Based on experience with other research reactors, specifically TRIGA reactors operating in the 1 to 2 MWt range, the annual release of gaseous and liquid effluents to unrestricted areas should be less than 30 curies and 0.01 curies, respectively.

No release of potentially harmful chemical substances will occur during normal operation. Small amounts of chemicals and/or high-solid content water may be released from the facility through the sanitary sewer during periodic blowdown of the cooling tower or from laboratory experiments.

Other potential effects of the facility, such as esthetics, noise, societal or impact on local flora and fauna are expected to be too small to measure.

Environmental Effects of Accidents

Accidents ranging from the failure of experiments up to the largest core damage and fission product release considered possible result in doses that are less than 10 CFR Part 20 guidelines and are considered negligible with respect to the environment.

Unavoidable Effects of Facility Construction and Operation

The unavoidable effects of construction and operation involve the materials used in construction that cannot be recovered and the fissionable material used in the reactor. No adverse impact on the environment is expected from either of these unavoidable effects.

Alternatives to Construction and Operation of the Facility

To accomplish the objectives associated with research reactors, there are no suitable alternatives. Some of these objectives are training of students in the operation of reactors, production of radioisotopes, and use of neutron and gamma ray beams to conduct experiments.

Long-Term Effects of Facility Construction and Operation

The long-term effects of research facilities are considered to be beneficial as a result of the contribution to scientific knowledge and training. Because of the relatively small amount of capital resources involved and the small impact on the environment, very little irreversible and irretrievable commitment is associated with such facilities.

Costs and Benefits of Facility Alternatives

The costs are on the order of several millions of dollars with very little environmental impact. The benefits include, but are not limited to, some combination of the following: conduct of activation analyses, conduct of neutron radiography, training of operating personnel and education of students. Some of these activities could be conducted using particle accelerators or radioactive sources which would be more costly and less efficient. There is no reasonable alternative to a nuclear research reactor for conducting this spectrum of activites.

Conclusion

The staff concludes that there will be no significant environmental impact associated with the licensing of research reactors or critical facilities designed to operate at power levels of 2 MWt or lower and that no environmental impact statements are required to be written for the issuance of construction permits or operating licenses for such facilities.

FACILITY LICENSE R-123

TECHNICAL SPECIFICATIONS

FOR THE

UNIVERSITY OF VIRGINIA

CAVALIER REACTOR

May 1985

DOCKET NO. 50-396

Amendment No. 4

TABLE OF CONTENTS

1.0 Definitions

The terms Safety Limit (SL), "Limiting Safety System Setting" (LSSS), "Limiting Condition of Operation" (LCO), "Surveillance requirements," and "design features" are as defined in 10 CFR 50.36.

Channel Calibration: A channel calibration is an adjustment of the channel so that its output responds, with acceptable range and accuracy, to known values of the parameter that the channel measures. Calibration shall encompass the entire channel, including equipment actuation, alarm, or trip.

Channel Check: A channel check is a qualitative verification of acceptable performance by observation of channel behavior. This verification should include comparison of the channel with other independent channels or methods of measuring the same variable, where this capability exists.

Channel Test: A channel test is the introduction of a signal into a channel to verify that it is operable.

Experiment: An experiment is (1) any apparatus, device, or material placed in the reactor core region (in an experimental facility associated with the reactor, or inline with a beam of radiation emanating from the reactor) or (2) any incore operation designed to measure reactor characteristics.

Experimental Facility: An experimental facility is any structure or device associated with the reactor that is intended to guide, orient, position, manipulate, or otherwise facilitate a multiplicity of experiments of similar character.

Explosive Material: Explosive material is any solid or liquid that is categorized as a Severe, Dangerous, or Very Dangerous Explosion Hazard

in "Dangerous Properties of Industrial Materials" by N.I. Sax, or is given an Identification of Reactivity (stability) index of 2, 3, or 4 by the National Fire Protection Association in its publication 704-M, "Identification System for Fire Hazards of Materials," also enumerated in the "Handbook for Laboratory Safety" published by the Chemical Rubber Company.

Fueled Experiment: A fueled experiment is any experiment that contains U-235 or U-233 or Pu-239. This does not include the normal reactor core fuel elements.

Measured Value: The measured value of the process variable is the value of the variable as it appears on the output of a measuring channel.

Measuring Channel: A measuring channel is the combination of sensor, lines, amplifiers, and output devices that are connected for the purpose of measuring the value of a process variable.

Movable Experiment: A movable experiment is one that may be inserted, removed, or manipulated while the reactor is critical.

On Call: To be on call refers to an individual who (1) has been specifically designated and the designation is known to the operator on duty, (2) keeps the operator on duty informed of where he may be contacted and the phone number, and (3) is capable of getting to the reactor facility within a reasonable time under normal conditions (e.g. approximately 30 minutes).

Operable: A component or system is operable when it is capable of performing its intended function in a normal manner.

Operating: A component or system is operating when it is performing its intended function in a normal manner.

Reactivity Limits: Quantities are referenced to ambient tank water temperature with the effect of Xenon poisoning on the core activity

accounted for if greater than or equal to 0.05% $\Delta k/k$. The reactivity worth of Samarium in the core will not be included in reactivity limits. The reference core condition will be known as the cold, xenon free critical condition.

Reactor Operation: The Reactor is in operation when not all of the shim rods are fully inserted and six or more fuel elements are loaded in the grid plate.

Reactor Safety System: The reactor safety system is that combination of measuring channels and associated circuitry that forms the automatic protective system of the reactor.

Reactor Secured: The reactor is secured when (1) all shim rods are fully inserted, (2) the console key is in the off position and is removed from the lock, and (3) no work is in progress in core involving fuel or experiments or maintenance of the core structure, control rods, or control rod mechanisms.

Reactor Shutdown: The reactor is in a shutdown condition when all shim rods are fully inserted.

Reportable Occurrence: A reportable occurrence is any of the conditions described in Section 6.4.2 of these specifications.

Secured Experiment: A secured experiment is any experiment, experiment facility, or component of an experiment that is held in a stationary position relative to the reactor by mechanical means. The restraining forces must be sufficient to overcome those to which the experiment might be subjected by hydraulic, pneumatic, buoyant or other forces that are normal for the operating environment of the experiment.

Shim Rod: A shim rod is a control rod fabricated from borated stainless steel, which is used to compensate for fuel burnup, temperature, and poison effects. A shim rod is magnetically coupled to its drive unit allowing it to perform the function of safety rod when the magnet is de-energized.

Surveillance Time Intervals

Annual - Interval not to exceed 15 months

Semi-annually - Interval not to exceed 7 1/2 months

Quarterly - Interval not to exceed 4 months

Monthly - Interval not to exceed 6 weeks

Weekly - Interval not to exceed 10 days

Daily - must be done during the calendar day

Tried Experiment: A tried experiment is (1) an experiment previously performed in this reactor or (2) an experiment for which the size, shape, composition, and location does not differ significantly enough from an experiment previously performed in this reactor to affect reactor safety.

True Value: The true value of a process variable is its actual value at any instant.

2.0 SAFETY LIMITS AND LIMITING SAFETY SYSTEM SETTINGS

2.1 Safety Limit

Applicability: This specification applies to the maximum temperature of the fuel or fuel cladding that could cause the uncontrolled release of fission product activity.

Objective: To assure that the reactor is operated in such a manner that the fuel cladding integrity is maintained to prevent an uncontrolled release of fission product activity that could adversely affect facility personnel and the general public.

Specification: The fuel consists of a U-AL alloy clad in aluminum. The safety limit is specified as the melting point of the fuel or cladding which is 1220°F or 660°C.

Basis: The melting point of aluminum is that temperature at which the fuel integrity would be breached, thereby causing an uncontrolled release of fission product activity. With the low power operating restrictions of the CAVALIER and considering the consequences of abnormal events as analyzed in the SAR, there is virtually no possibility that this temperature could ever be reached.

2.2 Limiting Safety System Settings

Applicability: This specification applies to limitations on setpoints pertaining to the thermal power level of the reactor and the water level above the fuel which would initiate an automatic shutdown of the reactor.

Objective: To assure that automatic protective actions are initiated in a manner consistent with maximizing safety for the reactor operators and minimizing the chance for their exposure, or the exposure of the public, to ionizing radiation.

Specification:

Maximum Reactor Power Level	100 watts
Minimum Tank Water Level	6.25 feet above top of fuel

Actual set-points may be set at more conservative values than those specified above.

Bases: The limitations on reactor power level and water height above the fuel was established by calculated radiation levels above the water level of the moderator tank as developed in section 3.2 of the CAVALIER SAR. The water height of 6.25 feet would lead to a dose rate of about 60 mr/hr above the reactor tank, at a power level of 100 watts, which

would produce a radiation level in the control room work area which is significantly less than 60 mr/hr (and 10 CFR Part 20 limits). The actual set-points for these parameters are normally set much more conservatively than the specification limits. Operating experience over the past 10 years with the power level at approximately 50 watts and the water level at approximately 8 feet has indicated a dose rate at the top of the tank at approximately 4 mr/hr and less than 1.0 mr/hr in the control room area.

3.0 LIMITING CONDITIONS FOR OPERATION

3.1 Power Operation

Applicability

This specification applies to the average power rating of the CAVALIER.

Objective

To assure that the reactor is operated in a manner consistent with maintenance of a low level of residual radioactivity in the fuel elements.

Specification

The Average Power Rating shall be less than 200 watt-hours/day where the averaging period shall not exceed 24 hours.

Bases

This rating will limit production of fission products to a level less than that analyzed in the Fission Product Released Section 9.4.4 of the CAVALIER SAR. This analysis indicates that the 2 hour doses at the site boundary after a very unlikely release of fission products from the fuel are within 10 CFR Part 20 averaged over a period of a year.

3.2 Reactivity

Applicability

These specifications apply to the reactivity condition of the reactor, and the reactivity worths of control rods and experiments.

Objective

The objective is to assure that the reactor can be shut down safely at all times, even with an experiment failure.

Specifications

The following specifications apply to the reactivity conditions for reactor operation.

(1) The minimum shutdown margin provided by control rods with secured experiments in place and referred to the cold, xenon free condition with the highest worth control rod fully withdrawn, is greater than 0.4% Δk/k.

(2) Any experiment with a reactivity worth greater than 0.35% Δk/k must be a secured experiment.

(3) The total reactivity worth of all experiments is less than 1.6% Δk/k and the reactivity worth of a single experiment is limited to 0.5% Δk/k.

(4) The excess reactivity including experiments in the core at any time shall be less than 1.6% Δk/k.

(5) The Alternate Reactivity Insertion System is operable.

These conditions must be met at all times with the following exceptions.

(a) With the ARIS system operable, the reactor may be operated up to 5 watts to measure the reactivity worth of experiments.

(b) The reactor may be operated up to 60 watts to calibrate control rods, after a major core configuration change, to determine if

specifications 3.2.1 through 3.2.4 are met. The ARIS system must be operable during all operations.

Bases

The shut down margin required by Specification 3.2(1) is necessary so that the reactor can be shut down from any operating condition and that it will remain shut down without further operator action.

The reactivity limitations in Specifications 3.2 (2) and (3) are based on the guidelines for "Development of Technical Specifications for Experiments in Research Reactors" given in Regulatory Guide 2.2 as developed in the CAVALIER SAR. The reactivity worth limitations of specifications 3.2 (2) for a secured experiment and 3.2 (3) for any single experiment limit the reactor period to approximately 2 seconds.

The reactivity of 1.6% Δk/k in specification 3.2(4) corresponds to a 6.9 millisecond period. Reactor core DU-12/25 of the SPERT-I series of tests had 12 plate fuel elements containing 168 grams of U-235 substantially similar to the CAVALIER fuel elements (Reference - Thompson and Beckerly, "Technology of Nuclear Reactor Safety," Volume I, page 683 (1964)). A 6.9 millisecond period was non-destructive to the SPERT reactor when shut down immediately following the excursion. See Chapter 9 of the CAVALIER SAR.

The boron addition capability of the ARIS provides additional assurance that the reactor can be shut down and maintained subcritical in the event of all four control rods failing to respond to a scram signal. See section 9.4.6 of the CAVALIER SAR.

3.3 Reactor Instrumentation

Applicability

This specification applies to the instrumentation which must be operable for safe operation of the reactor.

Objective

The objective is to require that sufficient information is available to the operator to assure safe operation of the reactor.

Specification

The reactor shall not be operated unless the measuring channels described in the following table are operable and the information is displayed on the control console.

Measuring Channel	Minimum No. Operable	Operating Mode in Which Required
Startup Count Rate	2	Reactor Startup
Linear Power (Gamma-Ion Chamber)	1	All Modes
Log N and Period (CIC)	1	All Modes
Tank Top Radiation Monitor	1	All Modes
Tank Water Level	1	All Modes

Bases

The neutron detectors, and gamma monitors, provide assurance that measurements of the reactor power level are adequately covered at both low and high power ranges. The reactor tank water level indicator provides early warning of the possibility of a leak in the Moderator Tank.

The radiation monitor provides information to operating personnel of a decrease in tank water level, or of high reactor power, or of any impending or existing danger from radiation, contamination, or streaming allowing ample time to take necessary precautions to initiate safety action.

3.4 Reactor Safety System

Applicability

This specification applies to the reactor safety system channels.

Objective

The objective is to stipulate the minimum number of reactor safety

system channels that must be operable during normal operation.

Specification

The reactor shall not be operated unless the safety system channels described in the following table are operable:

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 Rate	2	To prevent control rod withdrawal when both channels read <2 CPS	Reactor Startup
Manual Switch	1	Scram	All Modes
Reactor Power Level (CIC)	1	Scram	All Modes
Reactor Power Level (Gamma)	1	Scram	All Modes
Reactor Period (CIC)	1	Scram at less than 5 second period	All Modes
Reactor Period (Gamma)	1	Scram at less than 5 second period	All Modes

Bases

The startup interlock which requires a neutron count rate of at least 2 CPS on at least one startup count rate channel before the reactor is operated, assures that sufficient neutrons are available for proper operation of the startup channel. Power level scrams are provided to assure that the reactor power is maintained within the licensed limits. The manual scram allows the operator to shut down the reactor if an unsafe or abnormal condition arises. The period scrams are provided to

assure that the power level does not increase on a period less than 5 seconds. One period scram specified is the power level channel using the compensated ion chamber and the other period scram utilizes a gamma sensitive chamber. Specifications on the tank water level scram are included as safety functions in the event of a serious loss of moderator tank water. The reactor would be shut down automatically in the event that a major leak occurs in the tank. The analysis in Section 9.2 of the SAR for CAVALIER shows the consequences resulting from loss of this water; and in this event the area could be evacuated without difficulty before significant doses are received by personnel.

The tank-top radiation monitor provides a scram and gives audible and visual warning in the event of a high radiation level in the reactor room resulting from failure of an experiment, from a significant drop in tank water level, or a higher than planned power level.

3.5 Limitations on Experiments

Applicability

This specification applies to experiments installed in the reactor and its experimental facilities.

Objective

The objective is to prevent damage to the reactor or excessive release of radioactive materials in the event of an experiment failure.

Specifications

The following limits on experiments shall be met at all times:

(1) The reactivity worths of all experiments shall be in conformance with specifications in Section 3.2.

(2) Movable experiment must be worth less than 0.1% $\Delta k/k$.

(3) Experiments worth more than 0.1% Δk/k must be inserted or removed with the reactor shutdown except as noted in item (4).

(4) Previously tried experiments with measured worth less than 0.4% Δk/k may be inserted or removed with the reactor 2% or more subcritical.

(5) If any experiment worth more than 0.4% Δk/k is to be inserted in the reactor, a procedure approved by the Reactor Safety Committee shall be followed.

(6) All materials to be irradiated in the reactor shall be either corrosion resistant or encapsulated within corrosion resistant containers.

(7) Irradiation containers to be used in the reactor in which a static pressure will exist or in which a pressure buildup is predicted shall be designed and tested for a pressure exceeding the maximum expected by a factor of 2.

(8) Explosive material shall not be allowed in the reactor unless specifically approved by the Reactor Safety Committee. Experiments reviewed by the Reactor Safety Committee in which the material is potentially explosive, either while contained or if it leaks from the container, shall be designed to prevent damage to the reactor core or to the control rods or instrumentation, and to prevent any changes in reactivity.

(9) Experimental apparatus, material or equipment to be inserted in the reactor, shall not be positioned so as to cause shadowing of the nuclear instrumentation, interference with the control rods, or other perturbations that may interfere with the safe operation of the reactor.

Bases

The above specified limitations on experiments are based on the guidance given in Regulatory Guide 2.2 "Development of Technical Specifications

for Experiments in Research Reactors" as developed in Section 6 of the CAVALIER SAR and concern conservative requirements for protecting the reactor from materials to be used in experiments. The reactivity of less than 0.1% $\Delta k/k$ which can be inserted or removed with the reactor in operation in specification 3.5(2) can be compensated for by manual operation of a control rod.

3.6 Operation with Fueled Experiments

Applicability

This specification applies to the operation of the reactor with any fueled experiment.

Objective

To assure that the fission product inventory in fueled experiments are within the limits used in the safety analysis.

Specification

The reactor shall not be operated with fueled experiments unless the following conditions are satisfied.

(1) The thermal power (or fission rate) generated in the experiment is less than 1 watt (3.2×10^{10} fission/second).

(2) The total exposure of the experiment is not greater than the equivalent of 6 years continuous operation at 100 watts.

Basis

In the event of the failure of a fueled experiment, with the subsequent release of fission products (100% noble gas, 50% iodine, 1% solids), the 2 -hour inhalation exposures to iodine and strontium 90 isotopes at the facility exclusion distance, 70 meters, are less than the limits set by 10 CFR Part 20, using an averaging period of 1 year.

The analysis supporting this specification assumes 100% exfiltration of fission products from the reactor building in 2 hours. The safety analysis is identical with that in Section 5.4 of the UVAR Safety Analysis Report for isotopes released to the reactor building in general (other than in the UVAR reactor room). The CAVALIER is in the same building as the UVAR. The UVAR Safety Analysis Report is on record with the Commission: UVAR-18 (October, 1970), License NO. R-66, Docket No. 50-62. Due to the limits on reactivity worth of experiments in the CAVALIER, i.e. 0.5% $\Delta k/k$ for a single experiment, it is highly unlikely that a 1 watt fueled experiment could ever be run, however this is considered an upper limit for the purposes of analysis.

3.7 Rod Drop Times

Applicability

This specification applies to the time from the initiation of a scram to the time a rod starts to drop (release time), and to the time it takes for a rod to drop from the fully withdrawn to the fully inserted position (free drop time).

Objective

To assure that the reactor can be shut down within a specified interval of time.

Specification

The reactor shall not be operated unless:

(1) The release time for each of the shim rods is less than 100 milliseconds, and

(2) The free drop time for each of the shim rods is less than 700 milliseconds.

Bases

Rod drop times as specified are sufficiently short to be consistent with the reactor period and neutron level scram settings to assure that the LSSS will not be exceeded in a short period transient as shown in Section 9.3 of the CAVALIER-SAR.

3.8 Alternative Reactivity Insertion System (ARIS)

Applicability

This specification applies to the elemental boron in solution in the ARIS tank and to the ARIS isolation valve.

Objective

To assure that the ARIS is capable of providing an alternative means of reactor shutdown during all reactor operations.

Specification

The reactor shall not be operated unless the following conditions exist:

(1) The volume of solution in the ARIS tank is greater than 24 gallons.

(2) The concentration of the boron is greater than 0.129 lb/gal of solution.

(3) The ARIS valve is unlocked.

Bases

The boron solution in the ARIS tank will normally be kept at a volume of 25 gal. and a concentration of 0.144 lb of boron per gallon of solution. The combination of 24 gal. with a concentration of 0.129 lb of boron per gallon of solution will yield a total negative reactivity addition of 3.2% $\Delta k/k$ when uniformly mixed with the water in the moderator tank. The requirement that the ARIS valve be unlocked before reactor startups will preclude unnecessary delay in the system initiation in case of need.

4.0 SURVEILLANCE REQUIREMENTS

4.1 Shim Rods

Applicability

This specification applies to the surveillance requirements for the shim rods.

Objective

To assure that the shim rods are capable of performing their function and that no significant physical degradation in the rods has occurred.

Specification

(1) Shim rod drop times shall be measured semi-annually. Shim rod drop times shall also be measured if the control assembly is moved to a new position in the core or if maintenance is performed on the mechanism.

(2) The shim rod reactivity worths shall be measured whenever the rods are installed in a new core configuration.

Bases

The reactivity worth of the shim rods is measured to assure that the required shutdown margin is available and to provide means for determining the reactivity worths of experiments inserted in the core. The rod drop times are measured to assure that they meet the requirements of section 3.7 of these Technical Specifications.

4.2 Reactor Safety System

Applicability

This specification applies to the surveillance requirements for the safety system measuring channels and associated circuits of the reactor safety system.

Objective

The objective is to assure that the safety system is operable and capable of performing its intended function.

Specification

(1) A channel test of each of the reactor safety system channels shall be performed prior to each day's operation or prior to each operation extending more than one day.

(2) A channel check of each of the reactor safety channels shall be performed daily when the reactor is in operation.

(3) A channel calibration of the reactor safety channels shall be performed semi-annually.

Bases

The daily channel tests and channel checks will assure that the safety channels are operable. The semi-annual calibration will permit any long-term drift of the channels to be corrected.

4.3. Radiation Monitoring

Applicability

This specification applies to the radiation monitor required by Section 3.3 of these specifications.

Objective

The objective is to assure that the radiation monitor is operating and to verify the appropriate alarm setting.

Specification

The operation of the radiation monitor and the position of its associated alarm set point shall be verified daily during periods when the reactor is in operation. Calibration of the radiation monitoring equipment shall be performed semi-annually.

Bases

Surveillance of the monitor equipment will provide assurance that it is operable and that sufficient warning of a potential radiation hazard is available to permit corrective action before tolerances are exceeded.

4.4 Maintenance

Applicability

This specification applies to the surveillance requirements following maintenance of control or safety systems.

Objective

The objective is to assure that a system is operable before being used after maintenance has been performed.

Specification

Following maintenance or modification of a control or safety system component, it shall be verified that the system is operable prior to its return to service.

Bases

The intent of the specification is to assure that work on the system or component has been properly carried out and that the system or component has been properly reinstalled or reconnected.

4.5 Alternative Reactivity Insertion System (ARIS)

Applicability

This specification applies to the alternative reactivity insertion system.

Objective

To assure that the ARIS is operable and can provide sufficient reactivity to put the reactor in a subcritical condition.

Specification

(1) Prior to each day's operation the volume of solution in the ARIS tank shall be verified, and the leak detection trap will be observed for signs of leakage.

(2) The concentration of boron in the solution shall be determined semiannually or after each make-up addition to the ARIS tank.

(3) A flow test from the ARIS tank to the flanged tee will be performed annually and the results compared to similar tests run at initial startup.

(4) The section of pipe from the flanged tee to the bottom of the moderator tank will be blown out with air annually.

Bases

The daily verification and observation will provide a means of detecting leakage from the ARIS into the moderator tank which could cause unexpected reactivity fluctuations in the system. The concentration of the boron in the solution is determined periodically to assure that the ARIS is capable of providing a negative reactivity addition of 3.2% $\Delta k/k$. The flow tests and air tests will demonstrate that the ARIS valve is operable and that the pipes are free of obstructions.

5.0 DESIGN FEATURES

5.1 Reactor Fuel

Applicability

This specification applies to the fuel elements used in the reactor core.

Objective

The objective is to assure that the fuel elements used in the CAVALIER are the same as those considered in the Safety Analysis Report.

Specification

The fuel elements shall be of the materials testing reactor (MTR) type consisting of plates containing highly enriched uranium alloy fuel, clad with aluminum. There shall be 12 fuel plates containing nominally 165 grams of U-235 per element or 18 fuel plates containing nominally 195 grams of U-235 per element in the standard fuel elements. There shall be six fuel plates containing nominally 82.5 grams of U-235, per element or nine fuel plates containing nominally 98 grams of U-235, per element in the control rod fuel elements. Partially loaded fuel elements in which some of the fuel plates do not contain uranium may be used. An experimental element in which individual fuel plates can be removed or inserted may also be used. The mass of U-235 listed above refers to the initial (zero burnup) loading.

Various core configurations consisting of any combination of the above fuel elements may be used to accommodate experiments, but the loadings shall always be such that the minimum shutdown margin and excess reactivity as specified in Section 3.2 of these specifications are not exceeded.

Bases

These same type fuel elements have been run in the UVAR reactor at 2MW for many years and would create no safety problems for the CAVALIER. These specifications are consistent with the description of the fuel in the UVAR SAR.

5.2 Fuel Storage

Applicability

This specification applies to the storage of reactor fuel at times when it is not in the reactor core.

Objective

The objective is to assure that fuel which is being stored will not become supercritical and will not reach unsafe temperatures.

Specification

(1) All reactor fuel elements not in the reactor core shall be stored in a geometric array where k_{eff} is less than 0.9 for all conditions of moderation.

(2) Irradiated fuel elements and fueled devices shall be stored in an array which will permit sufficient natural convection cooling by water or air such that the fuel element or fueled device surface temperature will not exceed the boiling point of water.

Bases

Within these specifications, the fuel can be stored safelv under all conditions. the UVAR storage facility was constructed to meet these specifications and will be used to store the CAVALIER elements.

6.0 ADMINISTRATIVE CONTROLS

6.1 Organization

6.1.1 Structure

The reactor facility shall be an integral part of the School of Engineering and Applied Science of the University of Virginia. The organizational structure of UVA relating to the reactor facility is shown in Figure 6.1. The Chairman, Department of Nuclear Engineering will have overall responsibility for management of the facility (Level 1).

6.1.2 Responsibility

The Reactor Facility Director shall be responsible for the overall facility operation (Level 2). During periods when the Reactor Facility Director is absent, his responsibilities are delegated to the Reactor Supervisor (Level 3).

The Reactor Facility Director shall have at least a Bachelor of Science or Engineering degree and have a minimum of 5 years of nuclear experience. A graduate degree may fulfill 4 years of experience on a one-for-one time basis.

The Reactor Supervisor shall be responsible for the day-to-day operation of the UVAR and CAVALIER and for ensuring that all operations are conducted in a safe manner and within the limits prescribed by the facility license and the provisions of the Reactor Safety Committee. During periods when the Reactor Supervisor is absent, his responsibilities are delegated to a person holding a Senior Reactor Operator license (Level 4).

The Reactor Supervisor shall have the equivalent of a Bachelor of Science or Engineering degree and have at least 2 years of experience in Reactor Operations at this facility, or an equivalent facility, or at least 6 years of experience in Reactor Operations. Equivalent education or experience may be substituted for a degree. Within nine months after being assigned to the position, the Reactor Supervisor shall obtain and maintain an NRC Senior Operator license.

6.1.3 Staffing

When the reactor is operating the following conditions will be met:

(1) A licensed Senior Reactor Operator or a licensed Reactor Operator shall be present at the reactor controls, however, a trainee may be

present at the controls if under the direct supervision of Senior Reactor Operator or Reactor Operator in the control room. (2) A licensed Senior Reactor Operator shall be on call, but not necessarily at the facility.

(3) At least one other person, not necessarily licensed to operate the reactor, shall be present at the facility.

(4) Rearrangements of the core or other nonroutine actions shall be supervised by a licensed Senior Reactor Operator.

(5) A health physicist who is organizationally independent of the Reactor Facility Operations groups, as shown in Figure 6.1, shall be responsible for radiological safety at the facility.

6.2 Review and Audit

There shall be a Reactor Safety Committee that shall review and audit reactor operations to ensure that the facility is operated in a manner consistent with public safety and within the terms of the facility license. The Reactor Safety Committee shall report to the President of the University and advise the Chairman, Department of Nuclear Engineering, and the Reactor Facility Director on those areas of responsibility specified below.

6.2.1 Composition and Qualification

The Committee shall be composed of at least five members, one of whom shall be the Radiation Safety Officer of the University. No more than two members will be from the organization responsible for Reactor Operations. The membership of the Committee shall be such as to maintain a degree of technical proficiency in areas relating to reactor operation and reactor safety.

6.2.2 Charter and Rules

(1) A quorum of the Committee shall consist of not less than a majority of the full committee and shall include the Chairman or his designee.

(2) The Committee shall meet at least semiannually and shall be on call by the Chairman. Minutes of all meetings shall be disseminated to responsible personnel as designated by the Committee Chairman.

(3) The Committee shall have a written statement defining such matters as the authority of the Committee, the subjects within its purview, and other such administrative provisions as are required for effective functioning of the Committee.

6.2.3 Review Function

As a minimum the responsibilities of the Reactor Safety Committee include:

(1) review and approval of untried experiments and tests that are significantly different from those previously used or tested in the reactor, as determined by the Facility Director.

(2) review and approval of changes to the reactor core, reactor systems or design feature that may affect the safety of the reactor.

(3) review and approve all proposed amendments to the facility license, Technical Specifications, and changes to the standard operating procedures (discussed in Section 6.3 of these specifications).

(4) review reportable occurrences and the actions taken to identify and correct the cause of the occurrences.

(5) review significant operating abnormalities or deviations from normal performance of facility equipment that affect reactor safety.

(6) review reactor operation and audit the operational records for compliance with reactor procedures, Technical Specifications, and license provisions at least every two years.

6.3 Operating Procedures

Written procedures, reviewed and approved by the Reactor Safety Committee shall be in effect and followed for the items listed below. These procedures shall be adequate to ensure the safe operation of the reactor, but should not preclude the use of independent judgment and action should the situation require such.

(1) startup, operation, and shutdown of the reactor.

(2) installation or removal of fuel elements, control rods, experiments, and experimental facilities.

(3) actions to be taken to correct specific and foreseen potential malfunctions of systems or components, including responses to alarms, suspected system leaks and abnormal reactivity changes.

(4) emergency conditions involving potential or actual release of radioactivity, including provisions for evacuation, re-entry, recovery, and medical support.

(5) preventive and corrective maintenance operations that could have an effect on reactor safety.

(6) periodic surveillance (including test and calibration) of reactor instrumentation and safety systems.

Radiation control procedures shall be maintained and made available to all operations personnel.

Substantive changes to the approved procedures shall be made only with the approval of the Reactor Safety Committee. Changes that do not change the original intent of the procedures may be made with the approval of the Facility Director. All such minor changes to procedures shall be documented and subsequently reviewed by the Reactor Safety Committee.

6.4 Required Actions

6.4.1 Action To Be Taken in the Event a Safety Limit is Exceeded

In the event a safety limit is violated, the following actions shall be taken;

(1) The reactor shall be shut down and reactor operations shall not be resumed until authorized by the Commission.

(2) The occurrence shall be reported to the Reactor Facility Director and the Chairman of the Reactor Safety Committee, or their designee, as soon as possible, but not later than the next work day. Reports shall be made to the Commission in accordance with Section 6.6 of these specifications.

(3) A written safety limit violation report shall be made that shall include an analysis of the causes of the violation and extent of resulting damage to facility components, systems, or structures; corrective actions taken; and recommendations for measures to preclude reoccurrence. This report shall be submitted to the Reactor Safety Committee for review.

6.4.2 Action To Be Taken in the Event of a Reportable Occurrence

A reportable occurrence is any of the following conditions:

(1) any safety system setting less conservative than specified in Section 2.2 of these specifications.

(2) operating in violation of an LCO established in these specifications, unless prompt remedial action is taken.

(3) safety system component malfunctions or other component or system malfunctions during reactor operation that could, or threaten to, render the safety system incapable of performing its intended safety function, unless immediate shutdown of the reactor is initiated.

(4) an uncontrolled or unanticipated increase in reactivity in excess of 0.5% $\Delta k/k$.

(5) an observed inadequacy in the implementation of either administrative or procedural controls, such that the inadequacy could have caused the existence or development of an unsafe condition in connection with the operation of the reactor.

(6) abnormal and significant degradation in reactor fuel, and/or cladding, coolant boundary, or containment boundary (excluding minor leaks) where applicable that could result in exceeding prescribed radiation-exposure limits of personnel and/or environment.

In the event of a reportable occurrence, the following action shall be taken:

(1) The Director of the Reactor Facility shall be notified as soon as possible and corrective action shall be taken before resuming the operation involved.

(2) A written report of the occurrence shall be made which shall include an analysis of the cause of the occurrence, the corrective action taken, and recommendations for measures to preclude or reduce the probability of reoccurrence. This report shall be submitted to the Director and the Reactor Safety Committee for review.

(3) A report shall be submitted to the Nuclear Regulatory Commission in accordance with Section 6.6 of these specifications.

6.5 CAVALIER Operating Records

In addition to the requirements of applicable regulations, records (or logs) of the items listed below shall be kept in a manner convenient for review and shall be retained as indicated.

6.5.1 Records To Be Retained for a Period of at Least Five Years

(1) normal reactor operation

(2) principal maintenance activities

(3) experiments performed with the reactor

(4) reportable occurrences

(5) equipment and component surveillance activity

(6) facility radiation and contamination surveys

(7) transfer of radioactive material

(8) changes to operating procedures

6.5.2 Records To Be Retained for the Life of the Facility

(1) gaseous and liquid radioactive effluents released to the environs

(2) offsite environmental monitoring surveys

(3) fuel inventories and transfers

(4) radiation exposures for all personnel

(5) changes to reactor systems, components, or equipment that may affect reactor safety

(6) updated and corrected drawings of the facility

(7) minutes of Reactor Safety Committee meetings

6.6 Reporting Requirements

In addition to the requirements of applicable regulations (such as described in Regulatory Guide 10.1 "Compilation of Reporting Requirements for Persons Subject to NRC Regulations" and NUREG-1022, "Licensee Event Report System"), reports should be made to the U.S. Nuclear Regulatory Commission as follows:

6.6.1 Special Reports

(1) A phone or telegram report as soon as possible, but no later than the next working day, to the Office of Regional Administrator, N.R.C.

Region II, 101 Marietta Street, N.W. Atlanta, Ga. 30323, or current address.

(a) any accidental offsite release of radioactivity above permissible limits, whether or not the release resulted in property damage, personal injury, or exposure

(b) Any reportable occurrences as defined in Section 6.4.2 of these specifications

(c) any violation of a safety limit

(2) A written report within 14 days in writing to the Director of the Office of Nuclear Reactor Regulation, U.S.N.R.C. Washington, D.C. 20555, or current address ATTN: Document Control Desk with a copy to the Office of Regional Administrator, NRC Region II, 101 Marietta Street, N.W., Atlanta, Ga. 30323, or current address:

(a) any accidental offsite release of radioactivity above permissible limits, whether or not the release resulted in property damage, personal injury, or exposure

(b) any reportable occurrence as defined in Section 6.4.2 of these specifications

(c) any violation of a safety limit

(3) A written report within 30 days in writing to the Director of the Office of Nuclear Reactor Regulation US NRC, Washington D.C. 20555, or current address ATTN: Document Control Desk, with a copy to the Office of Regional Administrator, NRC, Region II, 101 Marietta Street N.W. Atlanta, Ga. 30323 or current address :

(a) any substantial variance from performance specifications contained in these specifications or in the SAR

(b) any significant change in the transient or accident analyses

as described in the SAR

(c) changes in personnel serving as Chairman of the Department of Nuclear Engineering, Reactor Facility Director, or Reactor Supervisor

(4) A written report within nine months after initial criticality of the reactor or within 90 days of completion of the startup test programs, whichever is earlier, to the Director, Office of Nuclear Reactor Regulation, US NRC, Washington, D.C. 20555, or current address ATTN: Document Control Desk, upon receipt of a new facility license, an amendment to the license authorizing an increase in power level or the installation of a new core of a different design than previously used. The report will include the measured values of the operating conditions or characteristics of the reactor under the new conditions, including

(a) total control rod reactivity worth

(b) reactivity worth of the single control rod of highest reactivity worth

(c) minimum shutdown margin both at ambient and operating temperatures

6.6.2 Routine Reports

A routine written report will be made by March 31 of each year to the Director, Office of Nuclear Reactor Regulation, US NRC, Washington, D.C. 20555, or current address ATTN: Document Control Desk, with a copy to the Office of Regional Administrator, NRC, Region II, 101 Marietta Street, N.W., Atlanta, Ga. 30323 or current address providing the following information:

(1) A narrative summary of operating experience (including experiments performed) and of changes in facility design, performance

characteristics, and operating procedures related to the reactor safety occurring during the reporting period. (2) A tabulation showing the energy generated by the reactor (in watt hours) and the number of hours the reactor was critical each quarter during the year.

(3) A report of the results of the safety-related maintenance and inspections. The reasons for corrective maintenance of safety-related items will be included.

(4) A report of the number of emergency shutdowns and inadvertent scrams, including their reasons and the corrective actions taken.

(5) A summary of changes to the facility or procedures, which affect reactor safety, and performance of tests or experiments carried out under the conditions of Section 50.59 of 10 CFR 50.

(6) A summary of the nature and amount of radioactive gaseous, liquid and solid effluents released or dischanged to the environs beyond the effective control of the licensee as measured or calculated at or prior to the point of such release or discharge.

(7) A description of any environmental surveys performed outside the facility.

(8) A summary of radiation exposures received by facility personnel and visitors, including the dates and time of significant exposures (greater than 500 mrem for adults and 50 mrem for persons under 18 years of age) and a summary of the results of radiation and contamination surveys performed within the facility.

Amendment No. 4

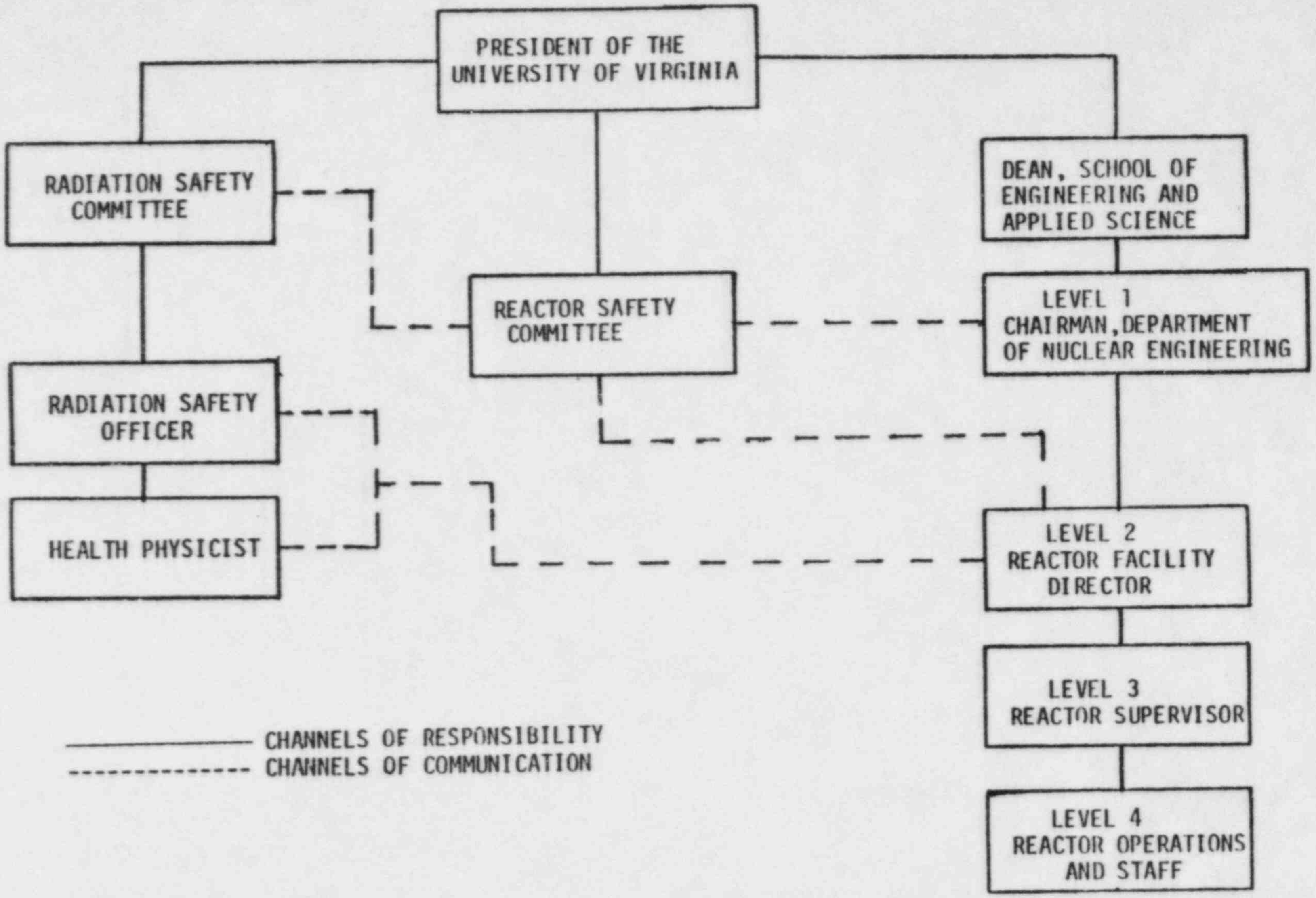

Figure 6.1 Organizational structure of UVA relating to reactor facility

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

NOTICE

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 1717 H Street, N.W.
   Washington, DC 20555

2. The Superintendent of Documents, U.S. Government Printing Office, Post Office Box 37082, Washington, DC 20013-7982

3. The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC Office of Inspection and Enforcement bulletins, circulars, information notices, inspection and investigation notices; Licensee Event Reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the NRC/GPO Sales Program: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, and NRC booklets and brochures. Also available are Regulatory Guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances*.

Documents available from the National Technical Information Service include NUREG series reports and technical reports prepared by other federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal and periodical articles, and transactions. *Federal Register* notices, federal and state legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free, to the extent of supply, upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, 7920 Norfolk Avenue, Bethesda, Maryland, and are available there for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

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

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)

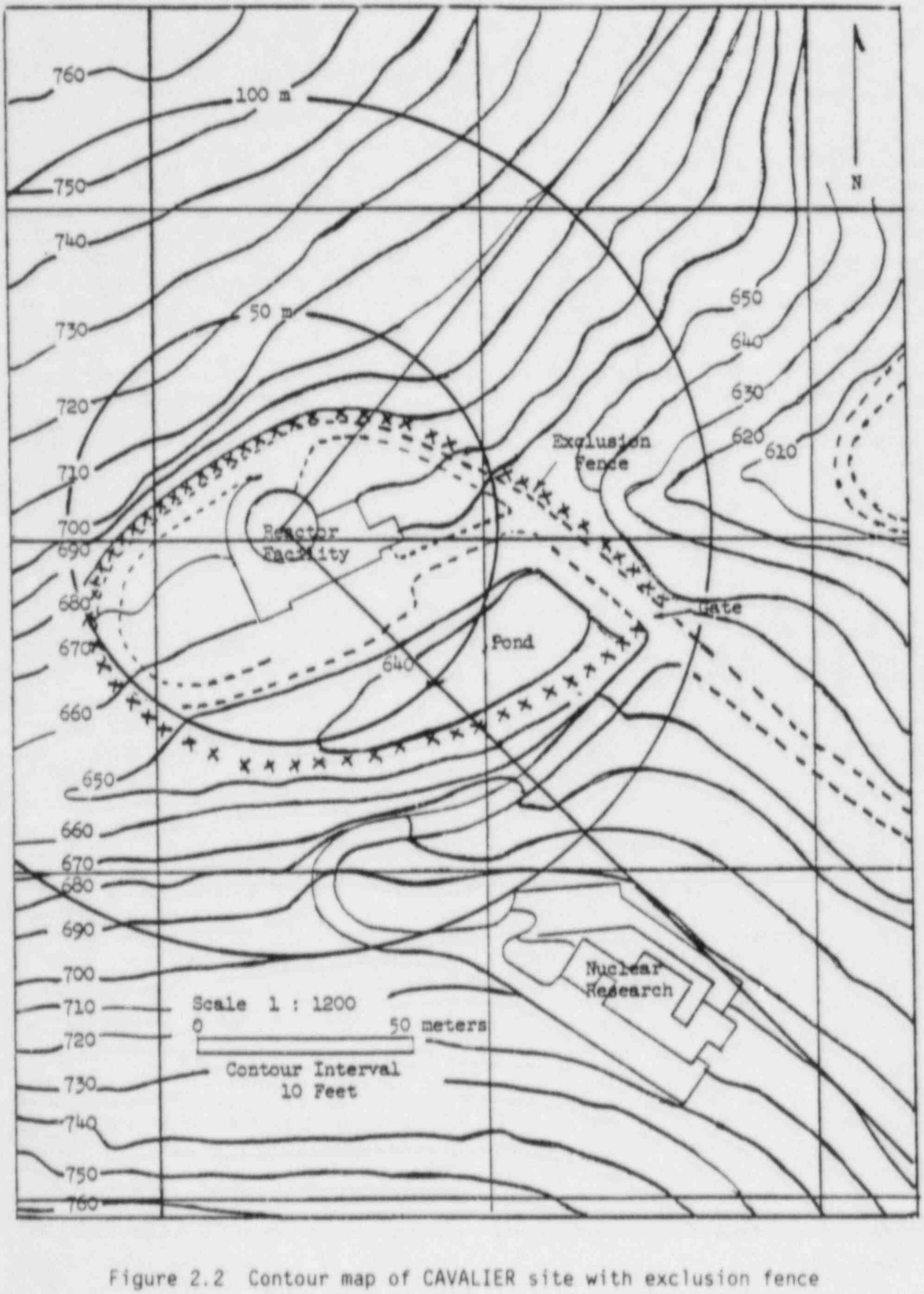

Figure 2.2 Contour map of CAVALIER site with exclusion fence

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 snow 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

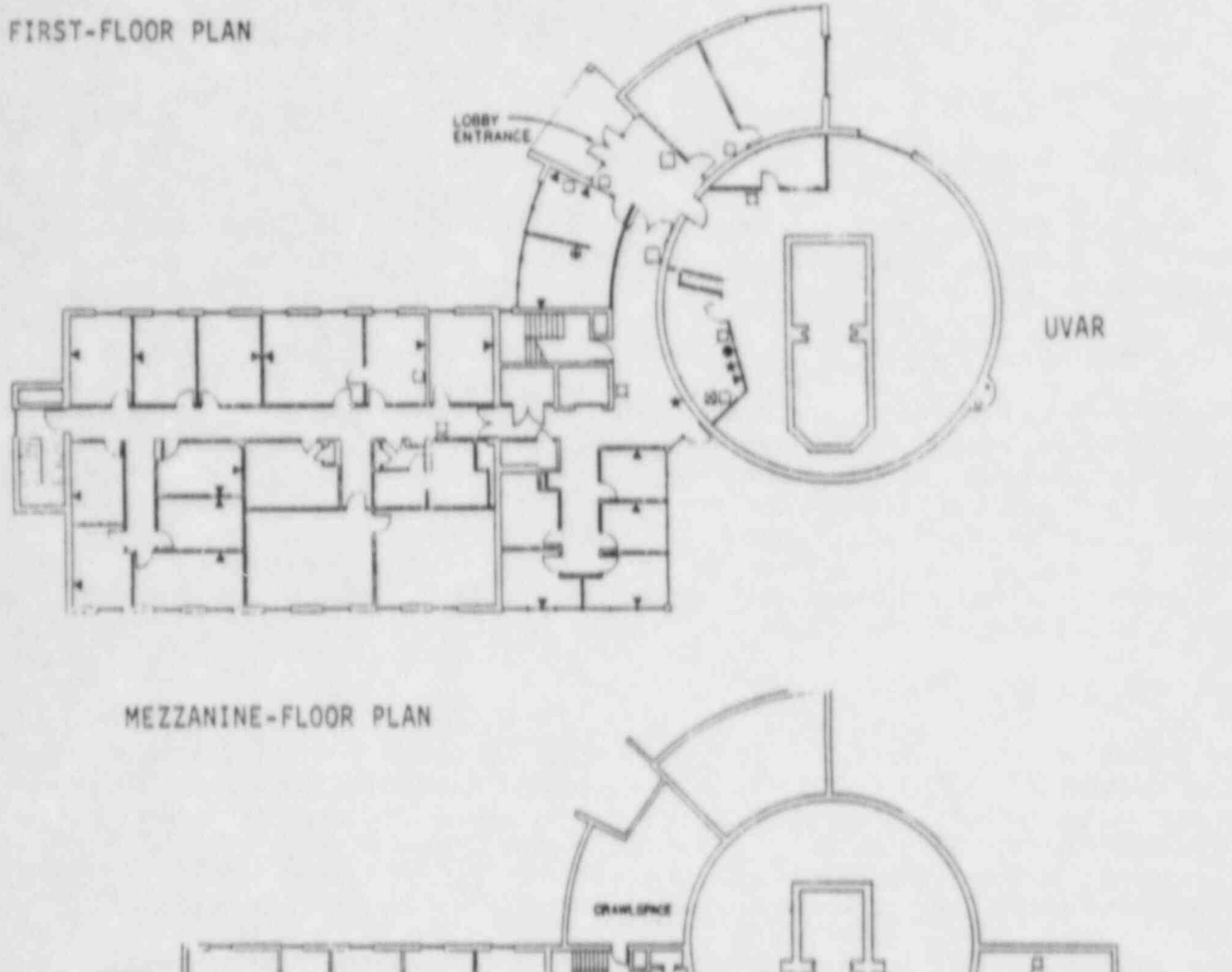

Figure 3.1 Plans for nuclear reactor facility

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	$U\text{-}Al_x$ 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% Δk/k (2.00$) above cold, clean, critical condition
Control rods (4)	~4.0% Δk/k (5.00$) (total)
Reactor cooling	Natural convection of bulk coolant
Reflector	Graphite or water
β_{eff}	0.8%
Reactivity Coefficient	
Temperature coefficient	-3.13×10^{-4} Δk/k/°C
Void coefficient	-1.90×10^{-3} Δk/k/% void

*Expected values for next core configuration loading.

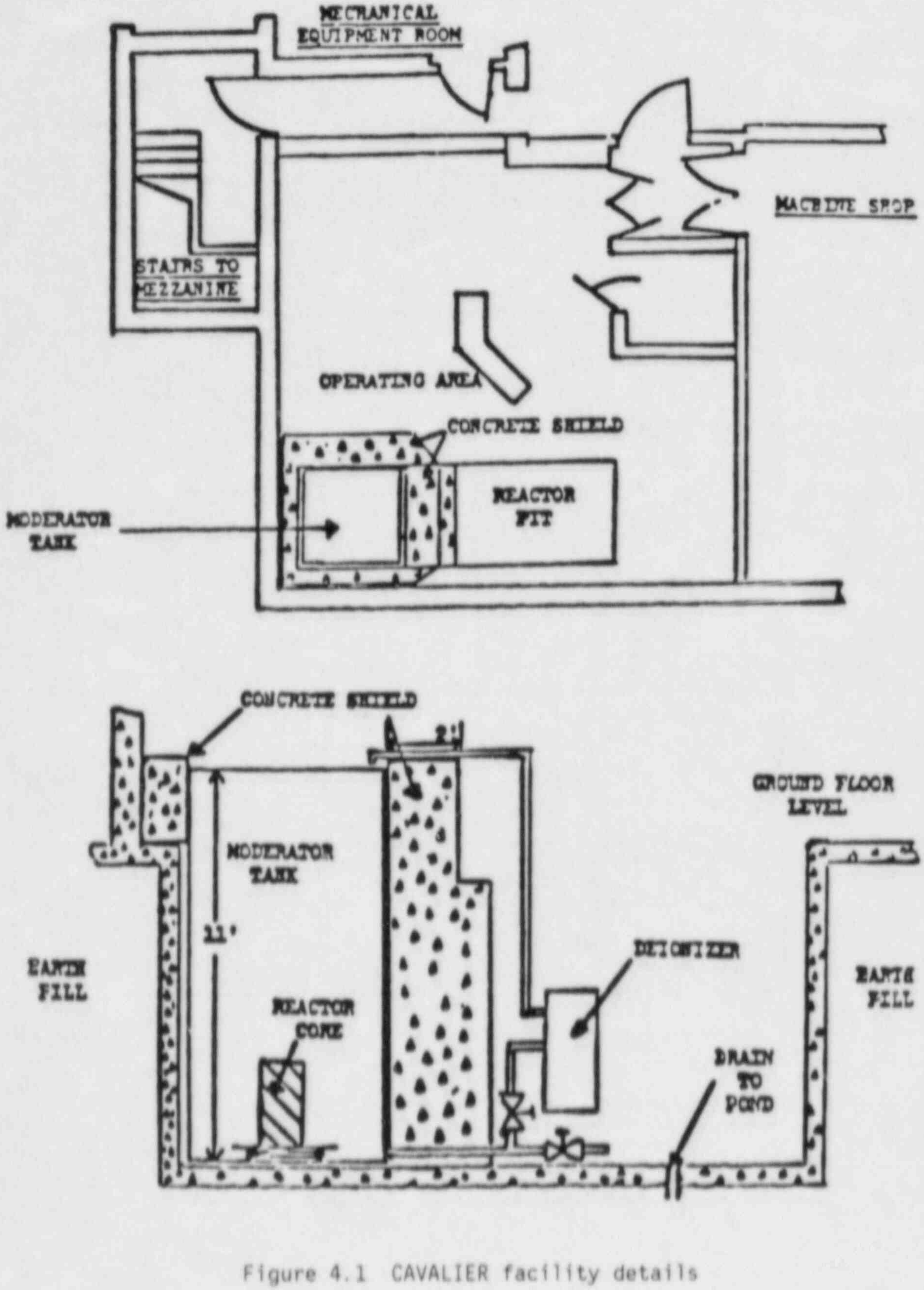

Figure 4.1 CAVALIER facility details

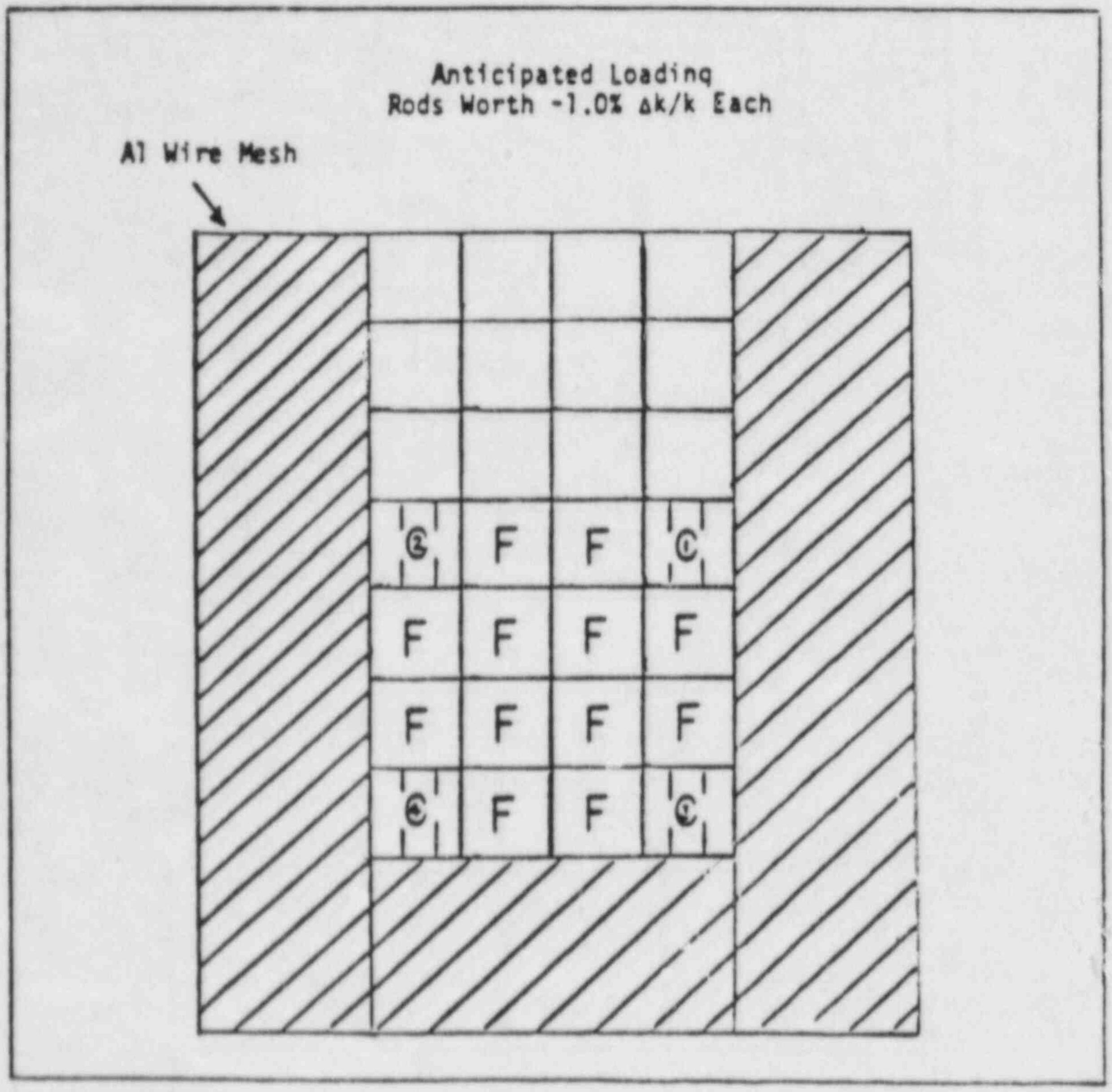

Figure 4.2 CAVALIER expected core configuration

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.

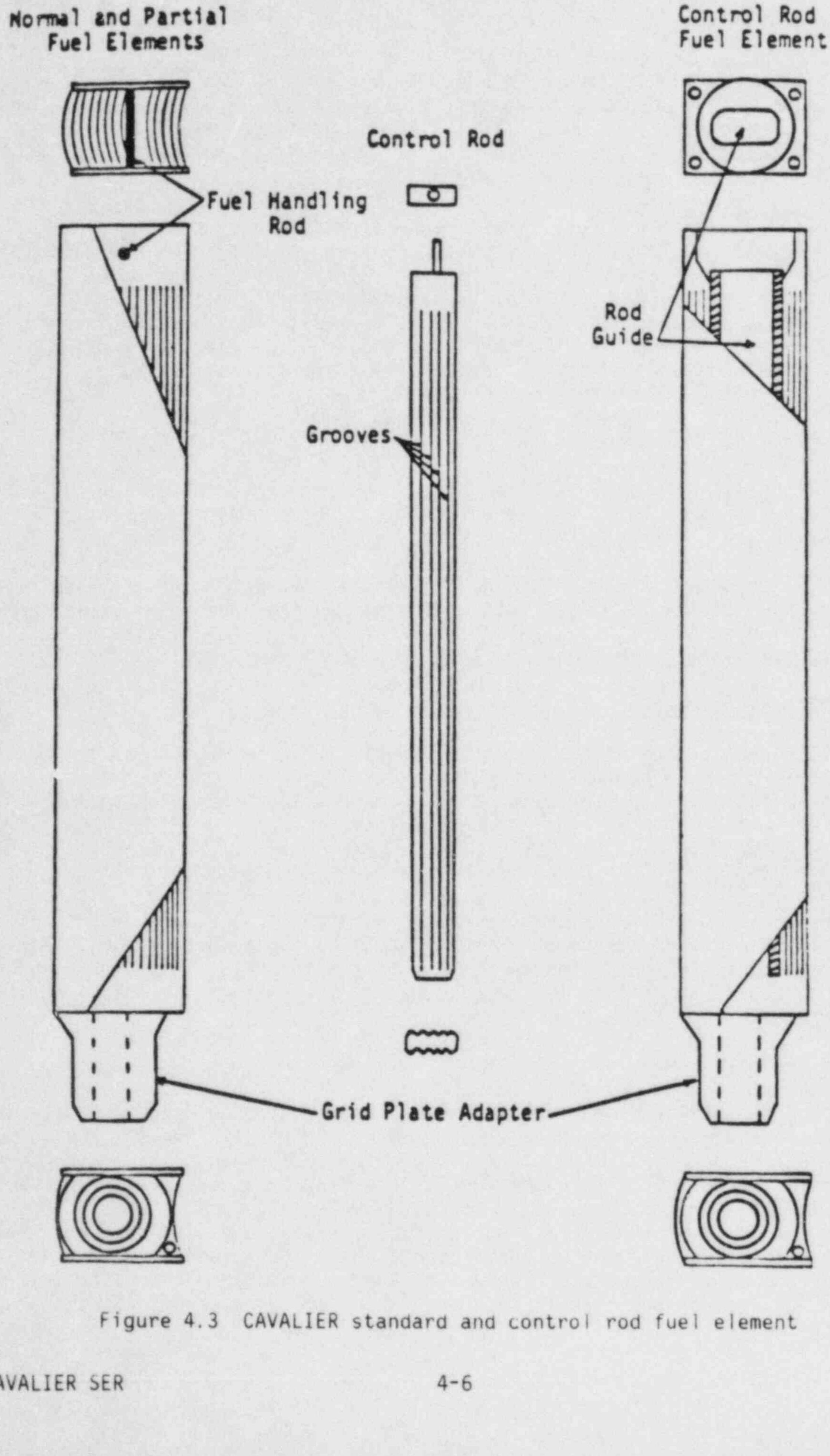

Figure 4.3 CAVALIER standard and control rod fuel element

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} $\Delta k/k/^{\circ}C$ and -1.90×10^{-3} $\Delta k/k/\%$ 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% $\Delta k/k$ (2.00$), and the minimum shutdown margin with the highest worth rod fully withdrawn to greater than 0.4% $\Delta k/k$. The total control rod worth is ~4.0% $\Delta k/k$ in the expected core configuration, and the highest worth rod is ~1.0% $\Delta k/k$ fully withdrawn. Thus, the minimum shutdown margin would still be maintained even if the core were loaded up to 2.6% $\Delta k/k$ 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% $\Delta k/k$. 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% $\Delta k/k$ 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.

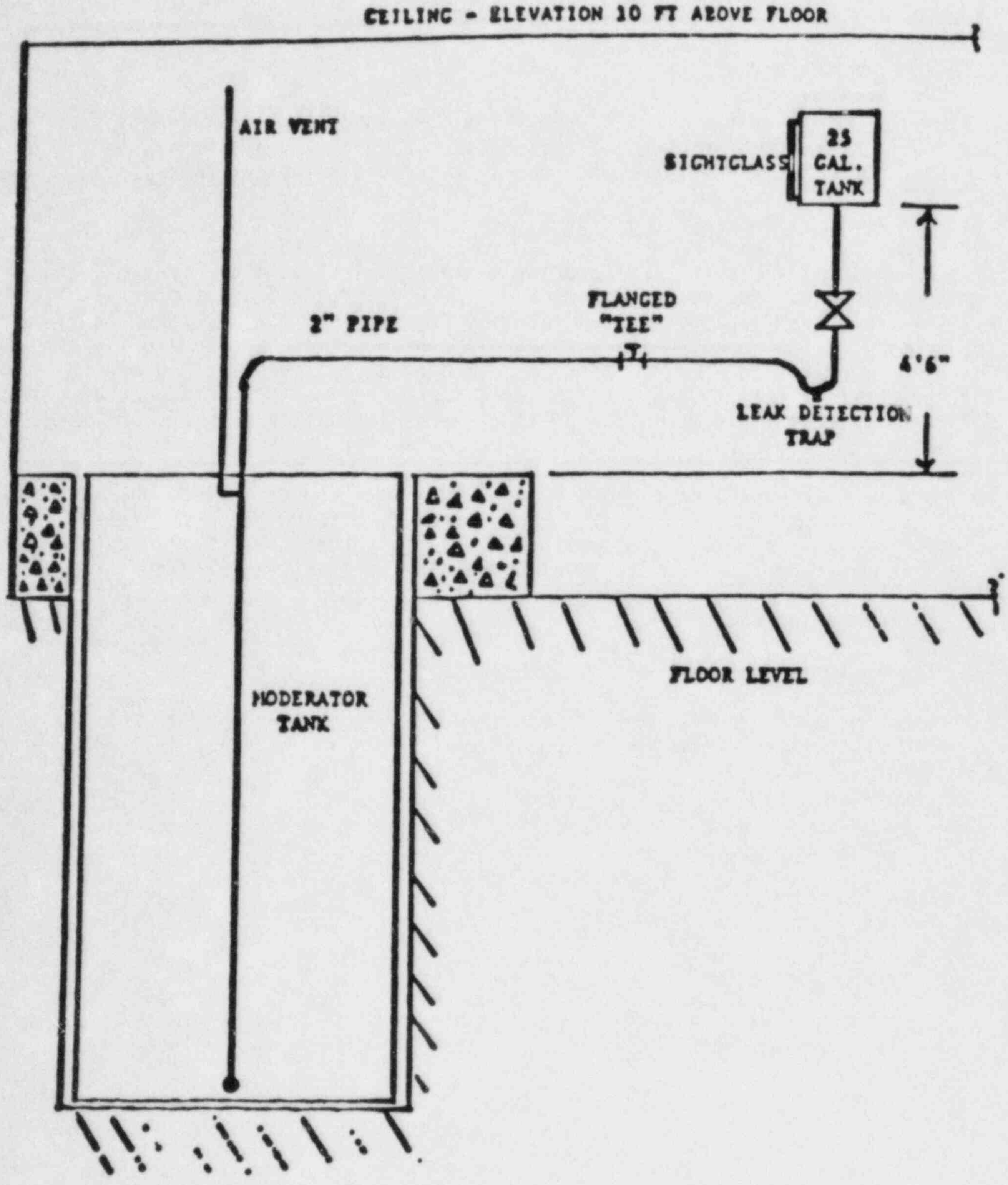

Figure 6.1 Alternate reactivity insertion system

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

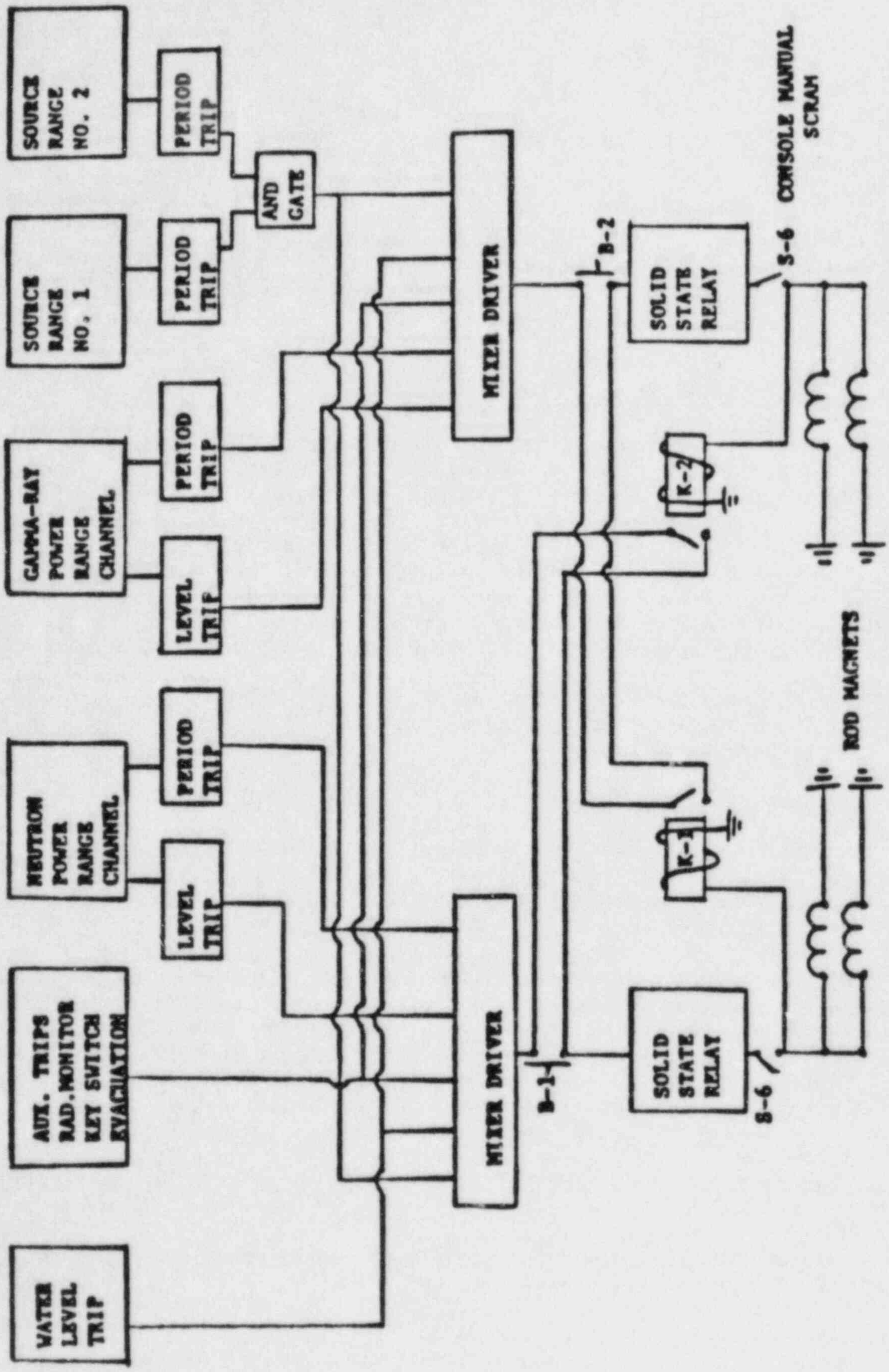

Figure 7.1 Block diagram of CAVALIER safety systems

(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

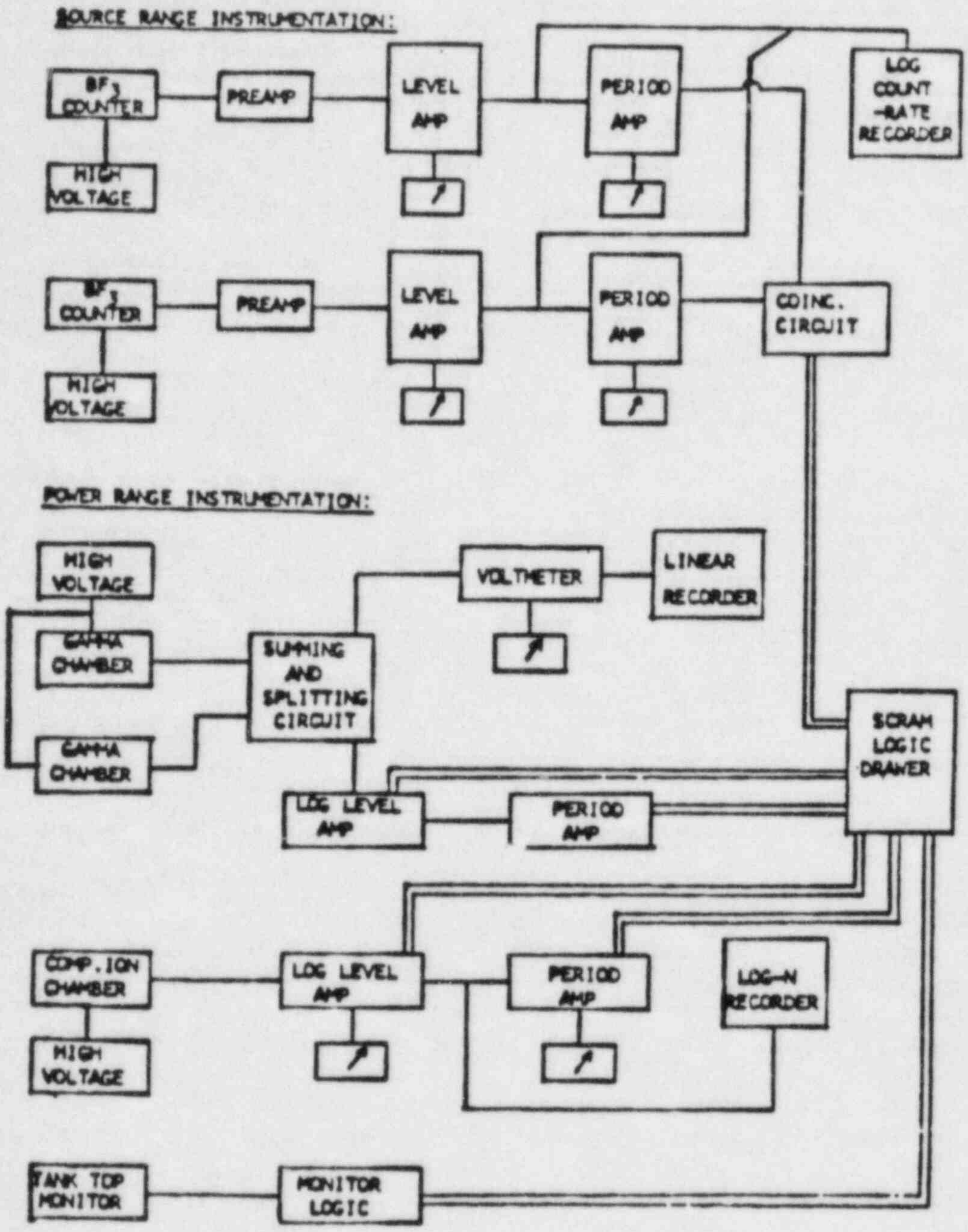

Figure 7.2 Block diagram of CAVALIER safety channels
Note: Double lines represent trip signals.

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 (≥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 operation 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.

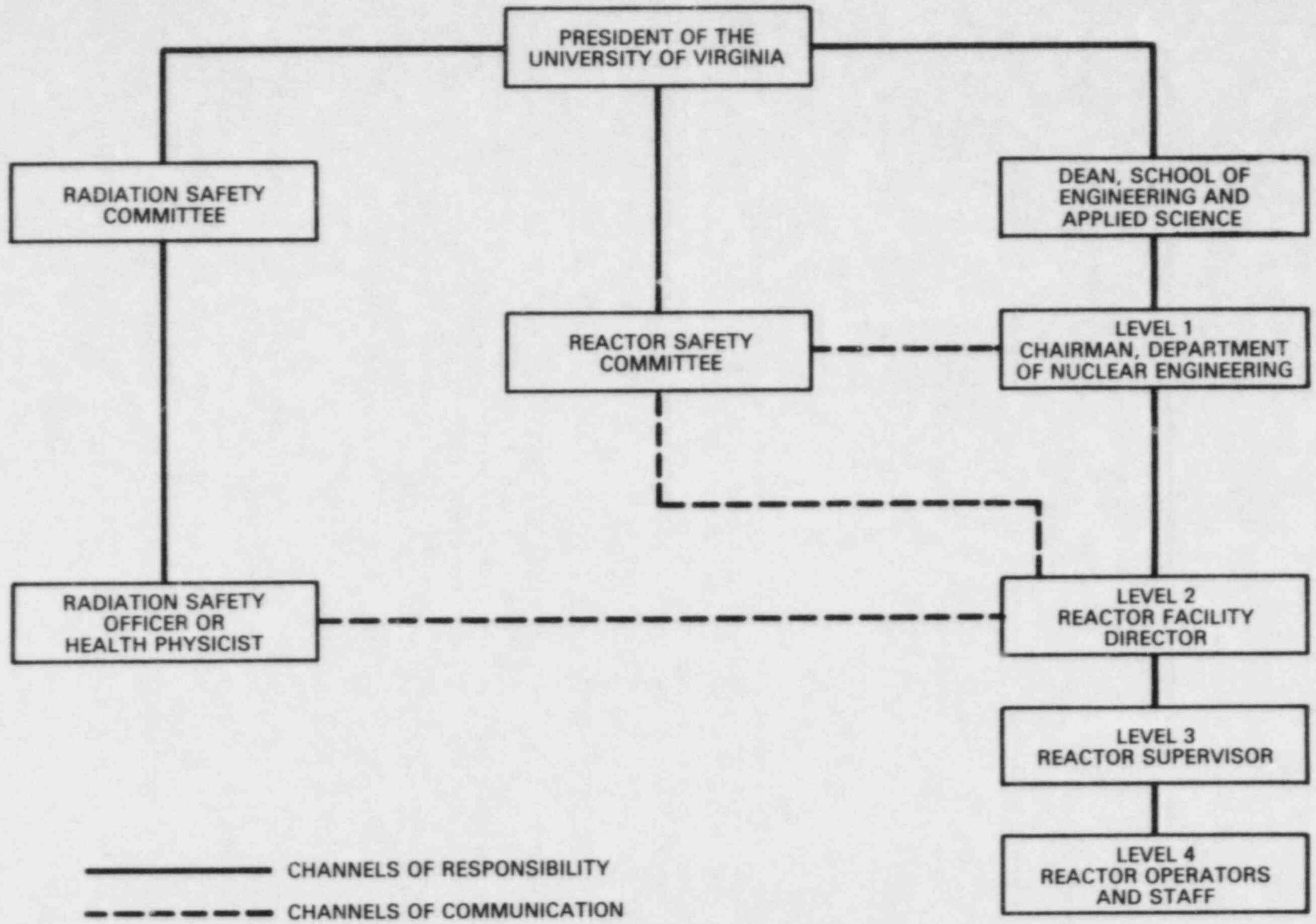

Figure 13.1 Organization of the reactor facility at the University of Virginia

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 Failure of a Fueled Experiment

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.

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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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