NUREG-1051

Safety Evaluation Report
related to the renewal of the operating license
for the research reactor at the
University of Kansas

Docket No. 50-148

U.S. Nuclear Regulatory
Commission

Office of Nuclear Reactor Regulation

May 1984

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ABSTRACT

This Safety Evaluation Report for the application filed by the University of Kansas (KU) for a renewal of Operating License R-78 to continue to operate the KU 250-kW open-pool training 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 Kansas and is located on the KU campus in Lawrence, Douglas County, Kansas. The staff concludes that the reactor facility can continue to be operated by KU without endangering the health and safety of the public.

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1 INTRODUCTION

The University of Kansas (KU) (licensee) submitted a timely application for renewal of the Class 104 Operating License (OL) R-78 for its open-pool training reactor by letter to the U.S. Nuclear Regulatory Commission (NRC) dated March 4, 1980 as amended. The letter requested renewal of the KU OL to permit continued operation at power levels up to and including 250 kW for a period of 10 years. KU is permitted to operate the reactor within the conditions stipulated in past amendments in accordance with Title 10 of the Code of Federal Regulations (10 CFR) Part 2.109 until NRC action on the renewal request is completed.

The renewal application, as amended, contains substantially all the information regarding the design of the facility included in the application for the original operating license. The application included a Hazards Summary Report, an Environmental Impact Appraisal, Technical Specifications, Emergency Plan, an Operator Requalification Program, a Fiscal Statement, and, under separate cover, a Physical Security Plan, which is protected from public disclosure under 10 CFR 2.790(d)(i) and 10 CFR 9.5(a)(4).*

The staff's technical safety review with respect to issuing a renewal operating license to KU has been based on the information contained in the renewal application and supporting appendices plus 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 (SER) was prepared by Angela T. Chu, Project Manager, Division of Licensing, Office of Nuclear Reactor Regulation, Nuclear Regulatory Commission. Major contributors to the technical review include the Project Manager and C.C. Thomas, C.E. Linder, and K.K.S. Pillay of the Los Alamos National Laboratory under contract to NRC.

The purpose of this SER is to summarize the results of the safety review of the KU open-pool training 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 KU facility at power levels up to and including 250 kW. The facility was reviewed against 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 specific accident-related regulations for research reactors, the staff has at times compared calculated dose values with related standards in

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*The Environmental Impact Appraisal data and Hazards Summary Report (known as Safety Analysis Report) were used as basic review documentation and are referenced throughout this report.

10 CFR 20, "Standards for Protection Against Radiation," both for employees and the public.

The University of Kansas training reactor (KUTR) initially was licensed at 10 kW on June 23, 1961. A license amendment authorizing operation at a maximum power level of 250 kW was issued on August 6, 1971. Since the power increase, license amendments concerning changes to the Technical Specifications and the Physical Security Plan were issued on March 4, 1980, and February 23, 1982, respectively.

1.1 Summary and Conclusions of Principal Safety Considerations

The staff's evaluation considered the information submitted by the licensee, past operating history recorded in annual reports submitted to the Commission by the licensee, and reports by the Commission's Office of Inspection and Enforcement. In addition, as part of the licensing review of several open-pool-type reactors, the staff obtained laboratory studies and analyses of several accidents postulated for the open-pool-type training reactor that are applicable to other reactors of 250 kW or less using materials-testing-reactor (MTR)-type fuel as does the KUTR. The staff's conclusions, based on evaluation and resolution of the principal issues reviewed for the KUTR, are as follows:

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

(2) The expected consequences of potential transients have been considered, including those of a maximum hypothetical accident (MHA). The staff performed conservative analyses of the more serious potential accidents and determined that the calculated potential radiation doses outside the reactor room would not exceed the dose guidelines of 10 CFR 20 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 method used for the control of radiological effluents can 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 provided by the licensee are such that the staff has determined that the licensee has 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 requirements of 10 CFR 73.

(8) The licensee's plan for operator requalification provides reasonable assurance that the reactor facility will be operated competently.

(9) The licensee's emergency plan, which is in compliance with the existing applicable regulations, has been found acceptable.

1.2 Reactor Description

The KUTR is an open-pool-type, heterogeneous assembly; the core is moderated and cooled by light water and is reflected by graphite on three faces and by water on the top, bottom, and one face. The MTR-type fuel elements, which can contain up to 10 fuel-bearing plates each, are of uranium-aluminum alloy clad with aluminum. The fuel is enriched to approximately 93% ^{235}U. The grid plate, which supports and positions the fuel elements, is fixed in location by attachment to the reactor tank.

The reactor core is located to one side near the bottom of a 6,600 gal tank that is cylindrical at the top. The walls of the tank near the bottom form a rectangular pocket in which the core is located. Graphite occupies the space outside the tank on three sides of the core.

The normal core configuration is composed of 13 standard fuel elements and 3 control rod fuel elements containing a total of 2.5 kg fully enriched uranium. Each control rod fuel element contains a control rod channel and 5 fuel-bearing plates, whereas the standard fuel element contains 10 fuel-bearing plates. The reactor is controlled by the three control rods and can be shut down by any one of the three control rods. The control rods, using boron carbide as the neutron absorption material, are used for shim-safety rods and the rod with the lowest worth also functions as a regulating rod. The reactivity worths of the three control rods in the current core are 1.99, 3.53, and 4.7% $\Delta k/k$. The total excess reactivity for this reactor is limited by Technical Specifications to 1.5% $\Delta k/k$.

1.3 Experimental Facilities

The KUTR is provided with multiple experimental facilities including four 6-in. diameter beam ports, a thermal column measuring 4 ft by 5 ft by 6 ft, a shield tank measuring 7.5 ft in diameter and 20 ft high, and a pneumatic conveyer. The experimental facilities are described in detail in Section 10.1 of this report.

1.4 Reactor Location

The KUTR is located in a building on the western edge of the main campus of the University of Kansas at Lawrence. Lawrence is situated on the banks of the Kansas River in the northeast corner of the State of Kansas, approximately midway between Kansas City and Topeka.

1.5 Shared Facilities and Equipment

The KUTR and the reactor building share no facilities or equipment with other buildings on the KU campus except utilities, such as electricity, gas, water, compressed air, and sewer system.

1.6 Comparison With Similar Facilities

The reactor is similar in design to several other operating open-pool-type, NRC-licensed facilities in the United States, as indicated in Table 1.1.

1.7 Design and Facility Modifications

A number of modifications have been performed on the KUTR since its startup in 1961. The more important modifications are addressed below.

In 1971, a 6-in.-thick polyethylene slab was installed on the thermal column door to provide additional shielding.

In 1973, a plastic cover was installed to cover the top of the reactor tank, considerably reducing the loss of reactor coolant from atmospheric evaporation.

In 1974, a carbon dioxide filtering system was installed in conjunction with the pneumatic system to prevent leakage of radioactive particles into the reactor area.

1.8 Operational History

The KUTR initially was authorized in 1961 to operate at power levels up to 10 kW. In 1971, after approximately 8,600 kW hours of operation, the licensee requested an amendment to operate the reactor at 250 kW for short periods of time. The amendment was granted, and the reactor was allowed to operate at 250 kW with 750 kW hours being the maximum allowable energy generated for any single operating period, followed by a recovery period sufficiently long so that the power average over the duration of the run would not exceed 10 kW. The reactor is not allowed to operate at above 10 kW level during the recovery period.

Since the power increase in 1971, the reactor has been operated approximately 15,300 KW hours. The total thermal energy generated from startup in June 1961 through June 1983 is approximately 24,000 KW hours and the total consumption of ^{235}U is approximately 1 g out of a total of 2.5 kg, or about 0.04% burnup.

Since 1978, the reactor has been operated at an average rate of 636 kW hours per year. Before 1978, the reactor was operated about 2,000 to 3,000 kW hours per year as a training reactor. However, in recent years, the reactor has been primarily used for radiobiological experiments and for demonstration purposes.

1.9 Nuclear Waste Policy Act of 1982

Section 302(b)(1)(B) of the Nuclear Waste Policy Act of 1982 provides that NRC may require, as a precondition to the issuance or renewal of an operating license for a research or test reactor, that the applicant shall have entered into an agreement with the Department of Energy (DOE) for the disposal of high-level radioactive waste and spent nuclear fuel. DOE has informed the NRC by letter dated May 3, 1983, that it has determined that universities and other government agencies operating nonpower reactors have entered into contracts with DOE that provide that DOE retain title to the fuel and is obligated to take the spent fuel and/or high-level waste for storage or reprocessing.

Because KU is such a university, it is in conformance with the Waste Policy Act of 1982.

Table 1.1 Other open-pool-type, NRC-licensed, nonpower reactors using MTR-type fuel

Facility	Power
Ohio State University	10 kW
Purdue University	1 kW
Rhode Island AEC	2 MW
Union Carbide	5 MW
University of Lowel	1 MW
University of Michigan	2 MW
University of Missouri (Columbia)	10 MW
University of Missouri (Rolla)	200 kW
University of Virginia	2 MW
Westinghouse NTR	10 kW

2 SITE CHARACTERISTICS

2.1 Geography and Demography

2.1.1 Geography

The KU campus is located in the southwestern section of Lawrence, Kansas, which is situated on the banks of the Kansas River in the northeast corner of the State, approximately midway between Kansas City and Topeka.

The reactor site is on the western edge of the campus in an area roughly defined by 11th Street on the north, Sunnyside Avenue and 16th Street on the south, Ohio Street on the east, and Naismith Drive and West Campus Road on the west.

Figure 2.1 shows the relation of the reactor site to the general area with superimposed concentric circles of radii at 500, 1,000, 1,500, and 2,000 ft. Figure 2.2 shows the layout of the campus.

2.1.2 Demography

Lawrence has a population of about 53,000 plus a student enrollment at the university of about 22,100. The surrounding country is devoted primarily to agriculture, although there is some industrial activity on the outskirts of the city to the north and east.

Buildings located within 500 ft of the reactor site are Learned Hall, Green Hall, Phi Kappa Psi fraternity, Pi Beta Phi sorority, and the Jayhawk Towers Apartment Building.

Learned Hall houses the School of Engineering. Green Hall houses the School of Law. The fraternity and sorority houses each accommodate about 75 students. Jayhawk Towers is a university apartment complex with four units, three of which are within 500 ft of the reactor site. Each unit contains 75 apartments that accommodate 3 to 4 students in each apartment. The four units of Jayhawk Towers accommodate approximately 1,200 students at maximum occupancy.

The Phi Kappa Psi fraternity house, approximately 170 ft from the reactor site, is the nearest residential building.

2.2 Nearby Industrial, Transportation, and Military Facilities

2.2.1 Transportation Routes

Principal transportation routes that are located close to the campus include State Road 10, known as 23rd Street, which is located approximately 1 mi south of the reactor site, and U.S. Highway 59, known as Iowa Street, which is located about 1,750 ft west of the reactor site, as shown in Figure 2.1. Interstate 70 is located about 2 1/2 mi north of the reactor site at its closest approach.

There are two freight lines near the campus. The Santa Fe Railroad passes through the north, south, and east of Lawrence, Kansas, along the south side of the Kansas River, and the Union Pacific Railroad passes through the northeast corner of Lawrence on the north side of the Kansas River. There is a small airport for commuter airplanes approximately 3 mi north of KU campus. The nearest commercial airport is located in Kansas City, approximately 25 mi northeast of Lawrence, Kansas.

2.2.2 Nearby Facilities

There are no heavy industries or major military establishments in the vicinity of the KU campus.

2.3 Meteorology

2.3.1 Climate

Kansas has a distinctly continental climate, with characteristically changeable temperatures and precipitation. In the warmer months of the year, the average mean temperature for this area is 56.6°F, with temperatures of 100°F or higher occurring on an average of 10 days per year. In the winter months, the average mean temperature is 32°F; temperatures of 0°F, or below, occur on an average of 2 to 4 days per year.

Average annual precipitation totals range from slightly more than 40 in. in southeastern Kansas to 30 to 35 inches in the northeast. Most of the precipitation is rain; about 75% of the year's total rainfall occurs from April to September. Snowfall averages close to 10 in. a year in south-central Kansas and increases gradually in other parts of the State to a maximum of 24 in. in the northwest.

2.3.2 Storms and Tornadoes

Northeast Kansas has average winds of about 10 mph. Maximum wind velocities of 50 mph are rather rare, though short gusts of greater speeds have been recorded. In Topeka, Kansas, approximately 25 mi northwest of Lawrence, Kansas, the mean frequency of thunderstorm activity is about 57 days per year. Prevailing winds are generally in a southerly direction, except during the colder months of December through March when the wind direction is generally from the north-northwest.

Tornadoes occur at irregular intervals in this area. The probability of a given square mile in the eastern third of Kansas being struck in any year by a tornado is only 1 in 1,620. This is based on the yearly average of 5.65 tornadoes that occur in the 27,386 mi2, constituting the eastern third of Kansas, and an average area of 3 mi2 covered by a single tornado. Tornado activity in this area usually occurs during the months of March through July and is usually accompanied by hail and strong winds.

2.4 Geology

A 6-year geological, geophysical, and seismological investigative program, partially funded by the NRC, has been completed by the Kansas Geological Survey (NUREG/CR-3117). These comprehensive investigations, while focusing on the seismicity and tectonic relationships of the Nemaha Uplift, a major geologic structure, the Midcontinent Geophysical Anomaly and associated features in the Midcontinent area, also include the Douglas County (Lawrence), Kansas, region. The Nemaha Uplift is a pre-Pennsylvanian age (at least 320 million years old) northeasterly trending, faulted anticline approximately 50 to 60 mi west of Lawrence extending from central Oklahoma through Kansas to southeast Nebraska. The Midcontinent Geophysical Anomaly is a buried belt of mafic rocks extending from Lake Superior to perhaps Oklahoma and lies west of the Nemaha Uplift.

Surface materials in the vicinity of the site consist of argillaceous-to-sandy colluvium with small amounts of gravel and weathered shale and have a thickness ranging from about 5 to 10 ft. Most of the colluvium is derived locally from the Pennsylvanian Age Lawrence shale and Oread limestone. The colluvial deposits and weathered shale overlie firm blue-gray argillaceous to sandy Lawrence shale having a thickness of 100 to 120 ft at the site.

On the basis of these studies, no geological or geophysical feature has been identified that may pose a potential hazard to the University of Kansas research reactor at Lawrence.

2.5 Hydrology

The local colluvial deposits have low-to-moderate permeability and will yield small amounts of ground water. The underlying, unweathered Lawrence shale has negligible-to-very-low permeability and will yield little or no water. There are no wells pumping ground water for domestic, stock, or other use within 1,000 ft of the site. The ground water table is intermittent in the area within a 500-ft radius of the site. In wet years the colluvial deposits may become saturated to within a few feet of the land surface and in dry periods may become nearly completely drained of ground water. Ground water at the site flows generally in a southerly direction.

2.6 Seismology

Lawrence, Kansas, lies within the Central Stable Region Tectonic Province. The largest earthquakes in this part of the Central Stable Region (Modified-Mercalli Intensity (MMI) VII) may have been associated with two structures--the Nemaha Uplift and Midcontinent Geophysical Anomaly. These structures are at least 50 mi west of Lawrence. There is a low level of seismicity in the vicinity of Lawrence, Kansas; the nearest events have intensities no greater than VI. MMI VI is described as "Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight" (Wood and Newman 1931).

On the basis of the review of tectonic information from the region, the staff concludes that the seismic hazard associated with this site is small.

2.7 Conclusions

The staff has evaluated the KUTR site for man-made as well as natural hazards and concludes that there are no significant hazards associated with this site that would render it unfit for continued operation.

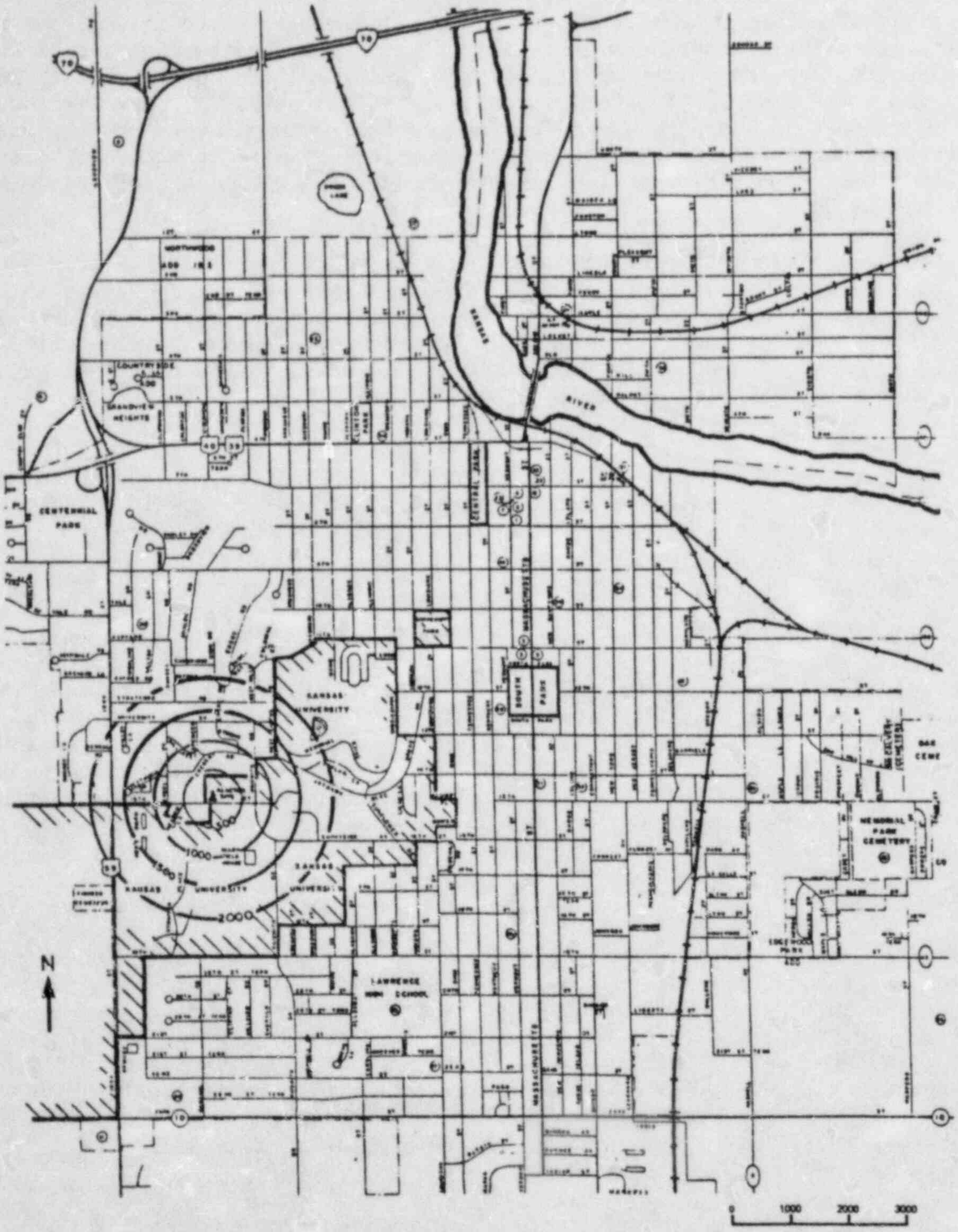

Figure 2.1 Major transportation routes located near the University of Kansas campus
Source: University of Kansas SAR

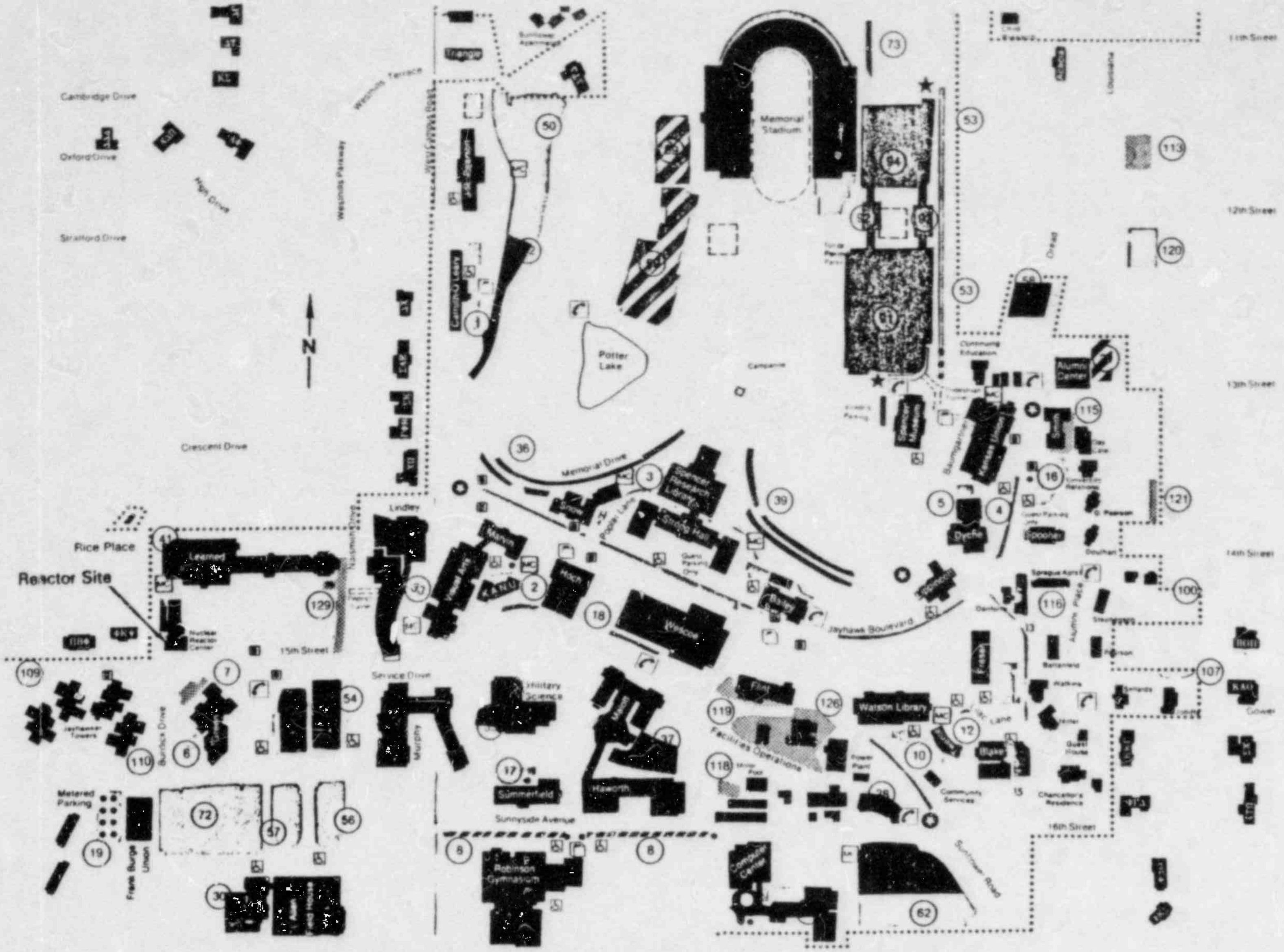

Figure 2.2 Reactor site at KU campus
Source: The University of Kansas

3 DESIGN OF STRUCTURES, SYSTEMS, AND COMPONENTS

3.1 Description of Confinement or Reactor Building

The reactor is located in a reinforced concrete, stone-faced building housing classrooms and laboratories in nuclear engineering, radiation biophysics, and radiation safety. The building has about 15,000 ft^2 of floor space with a reactor bay area of about 2,000 ft^2. The building has two stories; the lower floor is devoted mainly to nuclear engineering and radiation biophysics and the upper floor is devoted to radiation safety.

The entire building is air conditioned with separate units and there is no central air conditioning system. Each room, including the reactor bay, has its own outside air supply and vent. The circulating fan for the reactor bay has shutoff switches near the reactor control console and is equipped with devices for automatic closure of the area ventilation system.

The reactor bay is about 40 ft by 50 ft by 30 ft high. The reactor is oriented with the thermal column door facing south. A large door in the south wall serves as a truck door. The 5-ft diameter by 17-ft deep fuel storage pool, the reactor control center, and the demineralizer are located in the reactor bay. A 2-1/2 ton, monorail-mounted hoist near the reactor room ceiling services the reactor pool and storage pool.

Four laboratories open onto the reactor floor on the east and west sides. These laboratories are used for classes and research in nuclear engineering. Outside windows in the laboratories provide emergency exits. A radiochemical laboratory opens onto the reactor floor on the north side. The laboratory floor drain is connected to a holding tank for collection of radioactive spills. A lecture/demonstration room with windows that overlook the reactor floor is located on the second floor. There is no access to the reactor bay from this room. The only access to the reactor bay is through the first floor corridor and a door from the outside on the south wall.

The floor plans of the lower and upper floors are shown in Figures 3.1 and 3.2, respectively.

3.2 Wind Damage

Meteorological records of Kansas show that damaging tornadoes have occurred in the area but they are not considered common. In the eastern third of Kansas, the probability of a tornado in any year in a given square mile is only 1 in 1,620, as discussed in Section 2.3.2. Furthermore, there is a very low frequency of other severe storms with wind velocities in excess of 50 mph. The KUTR facility is located on the lower level of the two-story concrete, stone-faced building and the reactor is built inside a concrete shield, with a thickness ranging from 4 ft at the top to 8 ft at the bottom. Therefore, the staff concludes that wind damage to the KUTR is judged to be unlikely.

3.3 Water Damage

The reactor site has an elevation of about 960 ft above mean sea level (MSL). The city of Lawrence is located on the Kansas River, which is at an elevation of about 850 ft above MSL. Although the Kansas River does at times overflow its banks, there is no flood danger at the reactor site because it is at an elevation 110 ft above the river. The reactor site has adequate drainage and does not appear to be prone to water-caused damage.

3.4 Seismic-Induced Reactor Damage

Seismology of the region is discussed in Section 2.6 of this report. The KUTR is located in a seismically inactive area and the nearest events have Modified-Mercalli intensities no greater that VI, which can only cause insignificant damage to the concrete building housing the reactor. Because the reactor is built with features as described in Section 3.2 and the earthquake activities are minor, the staff concludes that damage to the reactor is unlikely from any infrequent seismic event.

3.5 Mechanical Systems and Components

The only mechanical system of importance to safety in the reactor is the control-rod-drive system. The control rods are coupled to the rod drive mechanisms by electromagnets. The drive mechanisms, which are actuated from the reactor control center, are located on the reactor superstructure. These systems and components have been operating since 1961 with a minimum of problems. By adhering to maintenance schedules and the performance requirements of the Technical Specifications, the mechanical systems and components have been maintained in good operational condition.

The staff concludes that the same attention will ensure the mechanical components and systems being maintained at an acceptable level of performance and will not increase the risk to the public.

3.6 Conclusion

From the above description and evaluation of the reactor facility, the staff concludes that the KUTR facility is adequate to withstand potential wind damage, water damage, and potential minor earthquake activity without any significant damage that would increase the risk to the public.

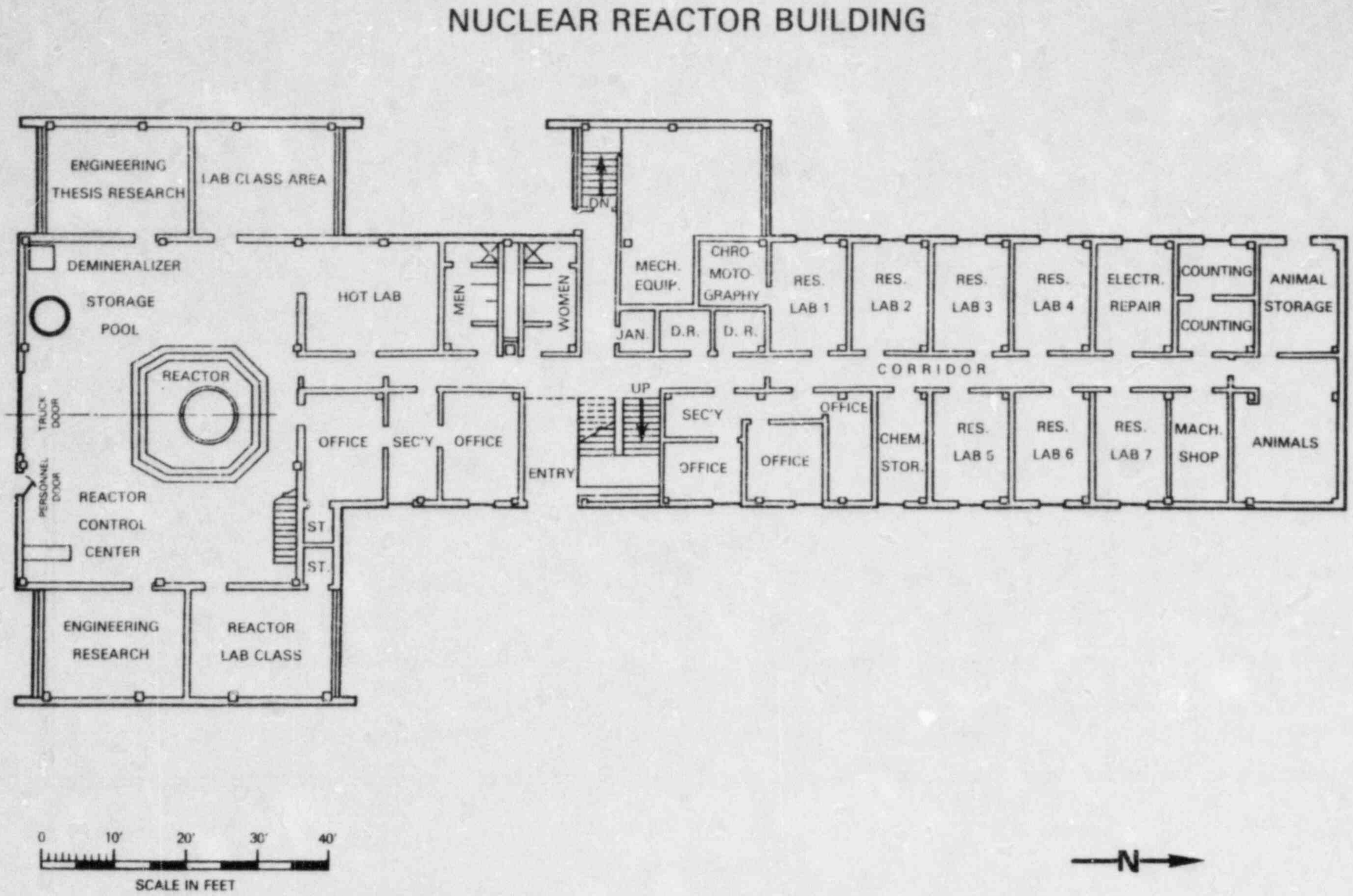

Figure 3.1 Nuclear reactor building, lower-level floor plan
Source: University of Kansas SAR

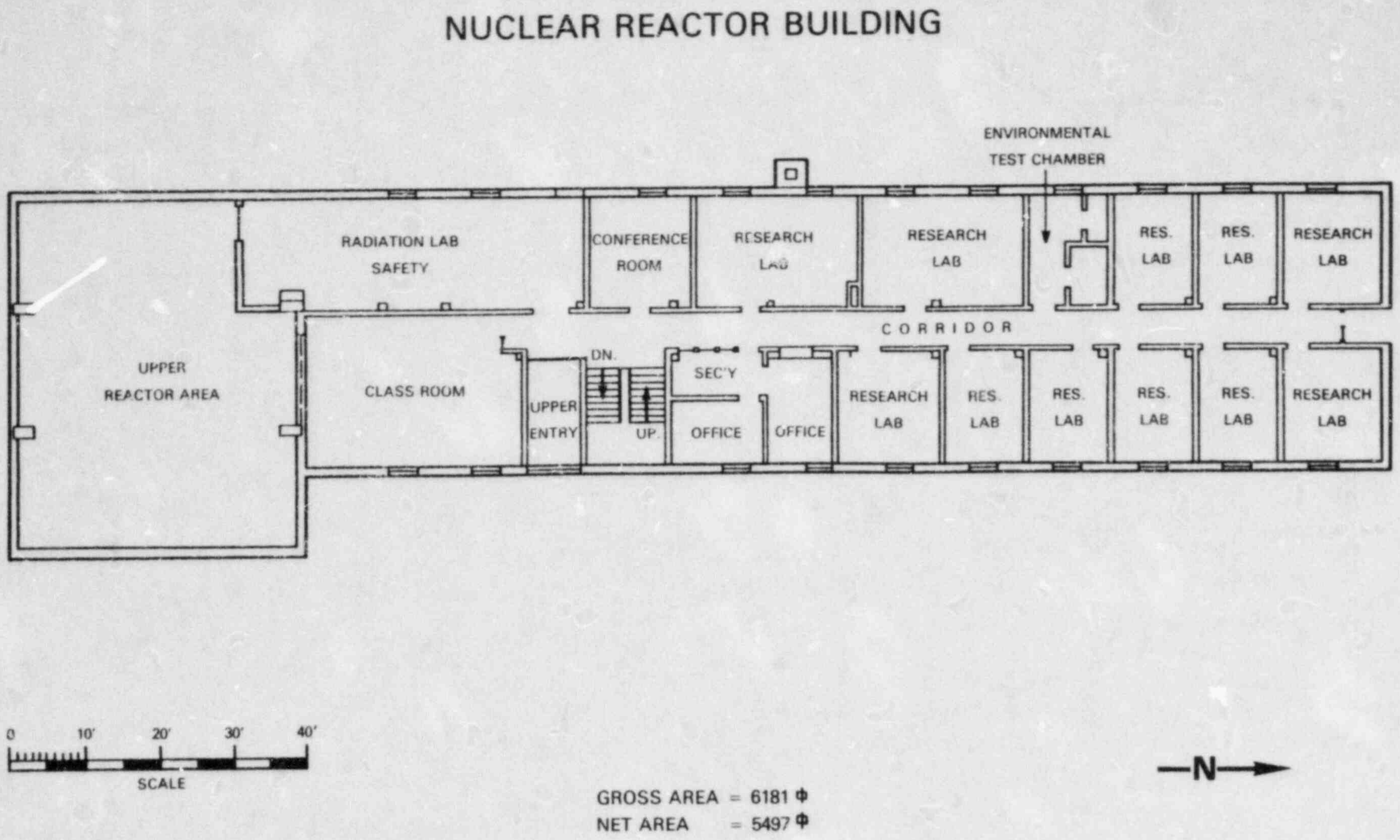

Figure 3.2 Nuclear rector building, upper-level floor plan
Source: University of Kansas SAR

4 REACTOR

The KUTR is an open-pool-type reactor using up to 2.5 kg of ^{235}U fuel enriched to approximately 93%. It is a heterogenous, light-water moderated and cooled, graphite and light-water reflected reactor that currently is authorized to operate at a steady-state power level of up to 250 kW. The KUTR generates no electricity and is used primarily for class instruction, student experiments, and research.

The discussion in the following sections is based on information obtained from licensee reports and during discussions with licensee personnel. The design and performance characteristics of the KUTR are summarized in Table 4.1. The general arrangement of the reactor is shown in Figures 4.1 through 4.5. The reactor building is discussed in Section 3.1.

4.1 Reactor Core

The core consists of 13 MTR-type fuel elements and 3 control rod fuel elements. Two different fuel loadings have been used with this reactor, and a reactor grid plate containing a 4-by-5 array of holes for positioning the fuel and control elements is provided.

4.1.1 Fuel Elements

The fuel elements are assemblies of fuel-bearing plates (Figure 4.5). Each plate is a sandwich of aluminum cladding over a uranium-aluminum alloy "meat." The meat is approximately 0.06 in. thick and contains about 17 g of ^{235}U enriched to 93%. The cladding is 0.02 in. thick. The overall dimensions of a fuel element are approximately 3.0 in. wide, 3.0 in. thick, and 35 in. long.

The fuel element consists of 10 fuel-bearing plates fastened with aluminum side plates so that the finished element has an almost square 3 in. by 3 in. cross-section. A guide piece is attached to the bottom end of the fuel element. The guide piece has a circular cross-section that fits in the positioning holes in the grid plate. A handle is attached to the top end of the fuel element and provides a means for inserting and removing of the fuel element.

There are three control rod elements that are identical to the fuel elements with the exception that the center five plates have been removed to provide space for the control rods. Guide plates prevent the control rod from contacting the fuel plates.

4.1.2 Control Rods

The power level in the KUTR is controlled by three control rods. Two rods are designated as shim-safety rods and the minimum-worth rod serves as a regulating rod. All three rods can be scrammed and fit into a central gap provided in special control rod fuel elements, as discussed in Section 4.2.1. The rods and their fuel elements can be located in any core position.

The lowest-worth control rod can be used as either a shim-safety or a regulating rod. Thus, in this report, discussions of aspects common to all rods will use the term rod. The terms shim-safety rod and regulating rod will be used when referring to those specific functions.

The shim-safety rods, which are used for both coarse and fine control, are made of Boral. The neutron-absorbing section of each shim-safety rod consists of two strips of Boral 0.32 in. thick, 2.06 in. wide, and 24.8 in. long. The Boral is about 35% by weight natural boron carbide. The reactivity worth of each shim-safety rod varies with the core loading and configuration. For the current core loading the reactivity worths for the two shim-safety rods are 3.53% and 4.70% $\Delta k/k$; the combined worth of these rods is 8.23% $\Delta k/k$.

As noted, the minimum-worth rod is used as a regulating rod and, as such, provides fine control of the reactor power level. When used as a regulating rod, it can be operated manually or automatically for servocontrol of the reactor power level. The worth of the regulating rod in the current core loading is 1.99% $\Delta k/k$.

Each rod is moved in and out of the reactor by an individual electromechanical system. The drive mechanisms, which are actuated from the reactor control center, are located on the reactor superstructure. The rod is suspended from the drive mechanism by an electromagnet. During normal operation, the shim-safety rods are driven either in or out at a rate of 5 in./min. When a scram signal is received, the magnets are de-energized and the rods drop freely into the core. Means are provided for automatic or manual scram, rod reversal, and rod inhibits to maintain the reactor in a safe operating range or for safe shutdown.

4.2 Reactor Tank

The watertight 0.38-in.-thick aluminum reactor tank is 7.5 ft in diameter by 20 ft deep and lines the reinforced concrete biological shield. The reactor support structure and core are located to one side of the reactor tank. The lower section of the reactor tank is formed to create a rectangular pocket to contain the fuel, control rods, the fuel element supporting structure, and the coolant inlet plenum chamber. The total volume of the reactor tank is 6,600 gal. When the tank is full the surface of the water is 16 ft above the top of the fuel.

Graphite occupies the space outside the lower tank section on three sides of the core and is separated from the biological shield by an aluminum liner. The fourth side is water reflected and serves as a bulk shielding facility.

Thimbles penetrate the bottom of the upper section of the reactor tank into the graphite to provide spaces for the startup source and the neutron detectors. The neutron detectors are in individual watertight containers.

The four 6 in.-diameter beam ports, penetrate the concrete biological shield and terminate in the graphite at the tank wall. The beam ports are located on the east and west sides of the reactor, and the thermal column is located on the south side. The pneumatic tube also terminates in the graphite.

4.3 Reactor Support Structure

The reactor core is supported by the grid plate, which is attached to the plenum chamber. There are 20 element-positioning holes in the grid plate arranged in a 4-by-5 array that permit circulation of coolant through the core. Auxiliary coolant holes between the positioning holes permit coolant flow between fuel elements. The plenum chamber, which channels coolant flow up through the fuel elements, is attached to the bottom of the reactor tank.

4.4 Reactor Instrumentation

The nuclear instrumentation provides the operator with information necessary for proper reactor operation. The following instrument channels are provided to monitor reactor parameters and are discussed in more detail in Section 7.

(1) count-rate or startup channel (fission chamber)
(2) linear power and automatic control channel
(3) log N power and period channel
(4) safety channel
(5) core outlet temperature

4.5 Biological Shield

The reactor core is shielded in the lateral direction by graphite and/or water and the concrete walls. Vertical shielding is provided by 16 ft of water above the core and 1 ft of water between the core and the tank floor. The concrete walls vary in thickness from top to bottom, being approximately 4 ft at the top and stepping to 8 ft at the bottom. A lead shield is incorporated in the thermal column near the side facing the core.

The staff concludes that the shielding, with the power level for operation of the reactor and the restriction of the radiation level in compliance with the Technical Specifications, is adequate to reduce external radiation exposure rates to acceptable levels.

4.6 Dynamic Design Evaluation

The reactor is provided with redundant rapid-response controls and nuclear instrumentation (Section 7) to attain versatile and safe operation. The reactor core system is designed to have negative temperature and void coefficients of reactivity. The ultimate void (total loss of coolant) removes the principal neutron moderator and shuts down the reactor.

The licensee and the staff have performed analyses of reactor dynamic behavior initiated by various changes in reactivity. The evaluation of an instantaneous change of reactivity is described below. A detailed evaluation of reactivity insertions by means of the control rods is discussed in Section 14.1.

4.6.1 Shutdown Margin

The Technical Specifications prescribe a minimum reactivity shutdown margin of 0.5% $\Delta k/k$ in a cold, xenon-free core with the highest-worth control rod fully withdrawn and the highest-worth movable experiment in the core in its most reactive state. In the current core, the reactivity worths of the two shim-safety rods are 3.53% and 4.70% Δk/k and the reactivity worth of the regulating rod is 1.99% Δk/k. The staff notes that the worth of the regulating rod should be considered in the calculation of shutdown margin because it functions as a third shim-safety rod under scram conditions. The maximum worth of a movable experiment is limited by the Technical Specifications to 0.4% Δk/k. Thus, the net reactivity in the core with the highest-worth rod fully withdrawn and the highest-worth movable experiment in its most reactive state is -5.12% Δk/k (-3.53 -1.99 -4.70 +4.70 +0.40). The maximum total excess reactivity that can be loaded in the core as per the Technical Specifications is 1.5% Δk/k, including the maximum-worth movable experiment. Therefore, the reactivity calculated above must be reduced by 1.1% Δk/k (+1.5 -0.4) for a core containing the maximum allowed total excess reactivity above the allowed maximum worth of a movable experiment. The net reactivity of such a core with the highest-worth rod fully withdrawn is -4.02% Δk/k (-5.12 + 1.1), which is well in excess of the required minimum shutdown margin of 0.5% Δk/k. The shutdown margin limitation provides adequate flexibility to load sufficient excess reactivity into the core to compensate for the effects of experiments, temperature coefficients of reactivity, and fission product poisoning while still ensuring that the reactor can be controlled even if both (1) the most reactive shim-safety rod were to fail to insert and (2) the maximum-worth movable experiment was displaced.

4.6.2 Excess Reactivity

Maximum excess reactivity in the KUTR core is limited to 1.5% Δk/k by the Technical Specifications. This amount provides for the effect of the negative power coefficient of reactivity at 250 kW, the negative reactivity effect of the maximum xenon level at 250 kW and an additional 1.2% Δk/k for experiments, uranium burnup, and operational flexibility. The licensee's calculations have shown that instantaneous 1.5% Δk/k reactivity insertions will not raise the temperature of the fuel plates to the melting point. Therefore, there is no danger of fission product release or damage to the structural integrity of the reactor as a result of an addition of reactivity equal to the total allowable excess reactivity in the system.

4.6.3 Experiments

The licensee's Technical Specifications provide limitations on the reactivity worths of secured and movable experiments. The staff has analyzed these limitations on the basis of information provided by the licensee in the Hazards Summary Report and the Technical Specifications.

The Technical Specifications limit the reactivity worth of a single secured experiment to 1.5% Δk/k with a limit of 1.5% Δk/k on the absolute worth of all experiments in the reactor and the associated experimental facilities at one time. On the basis of the BORAX experiments (Dietrich, 1954), the licensee has determined that a step reactivity insertion of 1.5% Δk/k would not result in damage to the KUTR fuel elements. Thus, the licensee has concluded that failure of a secured experiment or an accident resulting in displacement of all experiments in progress would not result in damage to the fuel elements. The analysis of a step reactivity insertion (designated the maximum hypothetical accident (MHA)) is considered in more detail in Section 14. Although the staff agrees with the licensee's conclusion, it notes that because the experiment absolute reactivity worth limitation of 1.5% Δk/k is equal to the maximum allowed excess reactivity limitation, it is unlikely that the reactor could go critical if the reactivity worth of experiments in the reactor and the experimental facilities is positive on removal (negative on insertion) and at the Technical Specification limit.

The Technical Specifications (1) define a movable experiment as one that can be inserted, removed, or manipulated while the reactor is critical and (2) limits the reactivity worth of any single movable experiment to 0.4% Δk/k and the sum of the absolute worths of all movable experiment to 1.2% Δk/k. The limitation for single movable experiments is well below the reactivity worth step insertion (1.5% Δk/k) that has been demonstrated not to cause fuel damage. Furthermore, the simultaneous movement of all movable experiments will not result in fuel or reactor component damage because the sum of the absolute worths of such experiments is limited to 1.2% Δk/k.

4.6.4 Conclusions

On the basis of the above information, the staff concludes that the experiments will not lead to a reactivity insertion that will pose a threat to the health and safety of the public. In addition, the staff concludes that with the highest-worth rod fully withdrawn and the maximum-worth movable experiment in the reactor, the reactor can still be adequately shut down under all required conditions.

4.7 Functional Design of Reactivity Control Systems

4.7.1 Control Rod Drives

The rods are driven by electromechanical linear actuators. An actuator is essentially a ball-bearing-type screw driven through a gear reduction unit by a low-inertia reversible motor. The drives for the rods are coupled to the control element by means of electromagnets. The drive mechanisms are actuated by switches from the control console. The limits of stroke of the control elements are set by adjustable cam-operated microswitches mounted on the rod drive mechanism. The three rods can be operated individually or the two shim-safety rods can be operated together. If electrical power is removed from the electromagnets, the rods fall into the core by gravity.

Shim-safety rods have console-mounted position indicators that can be read to 0.197 in. The rods also have control console-mounted annunciator lights for (1) rod insert limits, (2) rod seated, (3) manual or servo-operation of the rod being used as a regulating rod, and (4) the rods in contact with their magnet.

4.7.2 Scram-Logic Circuit

The KUTR is equipped with a scram-logic safety system that receives signals from core instrumentation (e.g., neutron flux detectors and other reactor parameters) to initiate a scram by removing power from the control rod magnets and/or the safety amplifier.

The reactor parameters that can initiate these scrams are

(1) high reactor power
(2) short period
(3) linear power high-voltage failure
(4) safety channel sigma amplifier failure
(5) operator manual scram

The safety system is discussed in more detail in Section 7.

4.7.3 Conclusions

The KUTR is equipped with a control system typical of nonpower reactors that incorporates multiple rods and multiple and redundant sensors that can initiate a scram. There is sufficient redundancy of rods so that the reactor can be shut down safely even if the most reactive shim-safety rod fails to insert upon receiving a scram signal.

In addition to the electromechanical safety controls for both normal and abnormal operation, the negative bulk temperature coefficient provides an inherent backup safety feature.

In accordance with the above and with the details presented in Section 7, the staff concludes that the reactivity control systems of the KUTR are designed and function adequately to ensure safe operation and safe shutdown of the reactor under all normal operating conditions.

4.8 Operational Practices

KU has implemented a preventive maintenance program that is supplemented by a detailed preoperational checklist to ensure that the reactor is not operated at power unless the appropriate safety-related components are operable. The reactor is operated by NRC-licensed personnel in accordance with explicit operating procedures, which include specified responses to any reactor control signal. All proposed experiments involving the use of the KUTR are reviewed by the Nuclear Reactor Committee for potential effects on the reactivity of the core or damage to any component of the reactor, as well as for possible malfunction of the experiment that might lead to the release of contained radioactivity.

4.9 Conclusions

The staff concludes that the KUTR is designed and built according to good industrial practices. It consists of standardized components representing many reactor-years of operation and includes redundant safety-related systems.

The staff review of the reactor facility has included studying its specific design, installation, and operational limitations as identified in the original and proposed Technical Specifications, revisions thereto, and other pertinent documents associated with the reactor. The design features are similar to those of the Bulk-Shielding Reactor at Oak Ridge National Laboratory, as well as other pool-type research reactors operating in many countries of the world. The fuel, which is an aluminum-clad, highly enriched, uranium-aluminum alloy, is used in over 30 research and test reactors in the United States and is very similar to the fuel used in the BORAX and SPERT tests. On the basis of its review of the KUTR and its experience with similar facilities, the staff concludes that there is reasonable assurance that this reactor is capable of continued safe operation, as limited by its Technical Specifications.

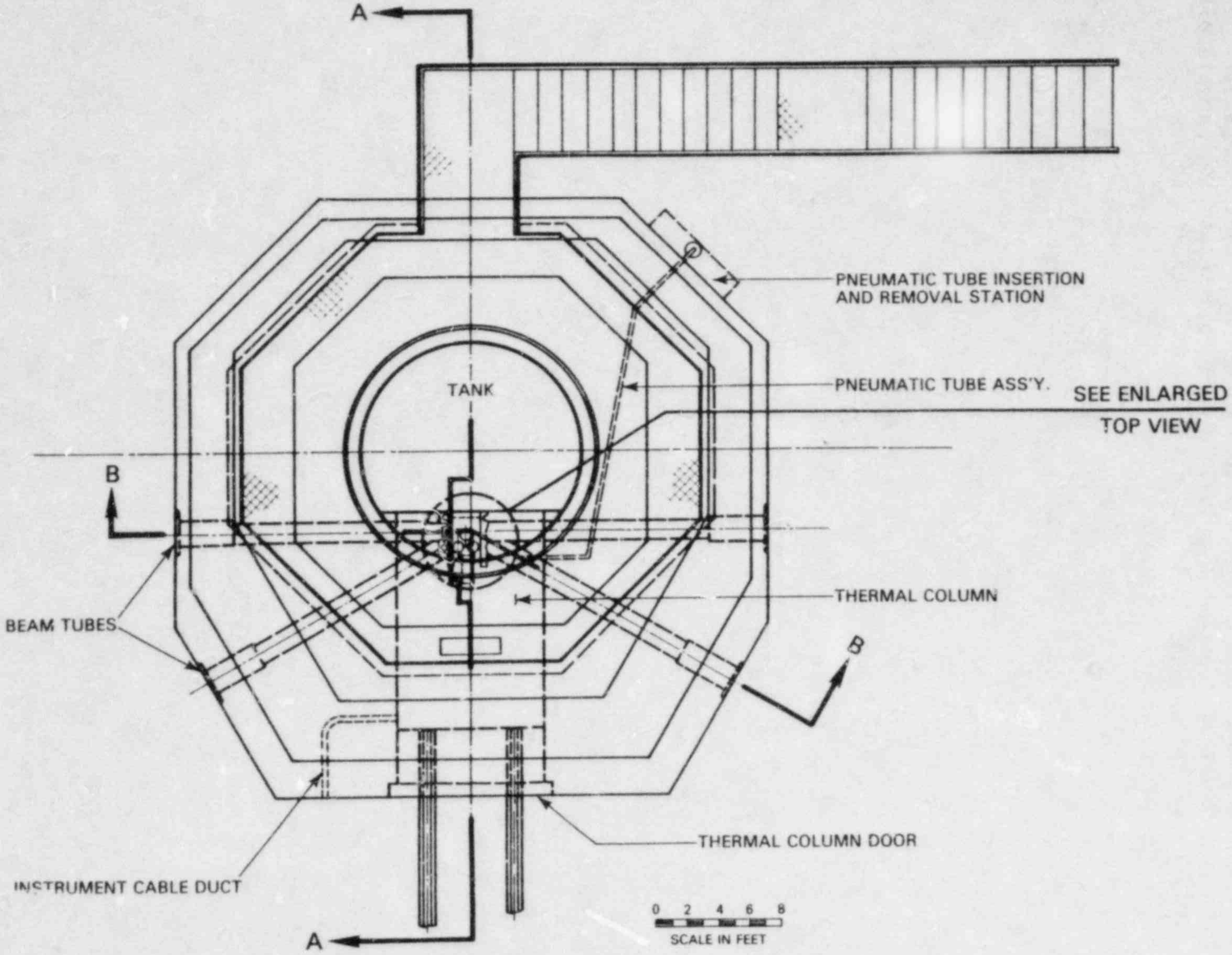

Figure 4.1 Top view of the reactor
Source: University of Kansas SAR

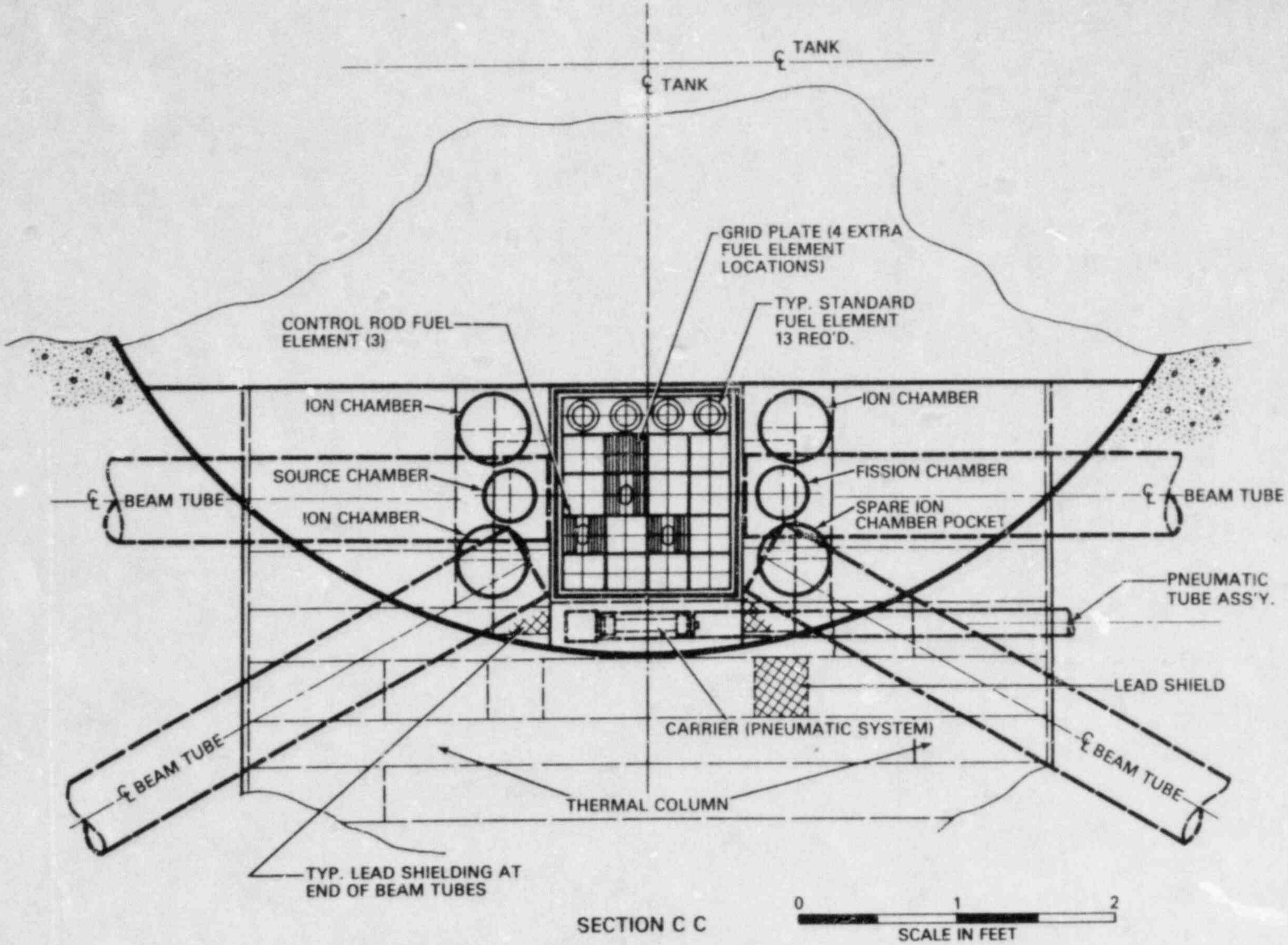

Figure 4.2 Enlarged top view of the reactor
Source: License Application (Docket 50-148)

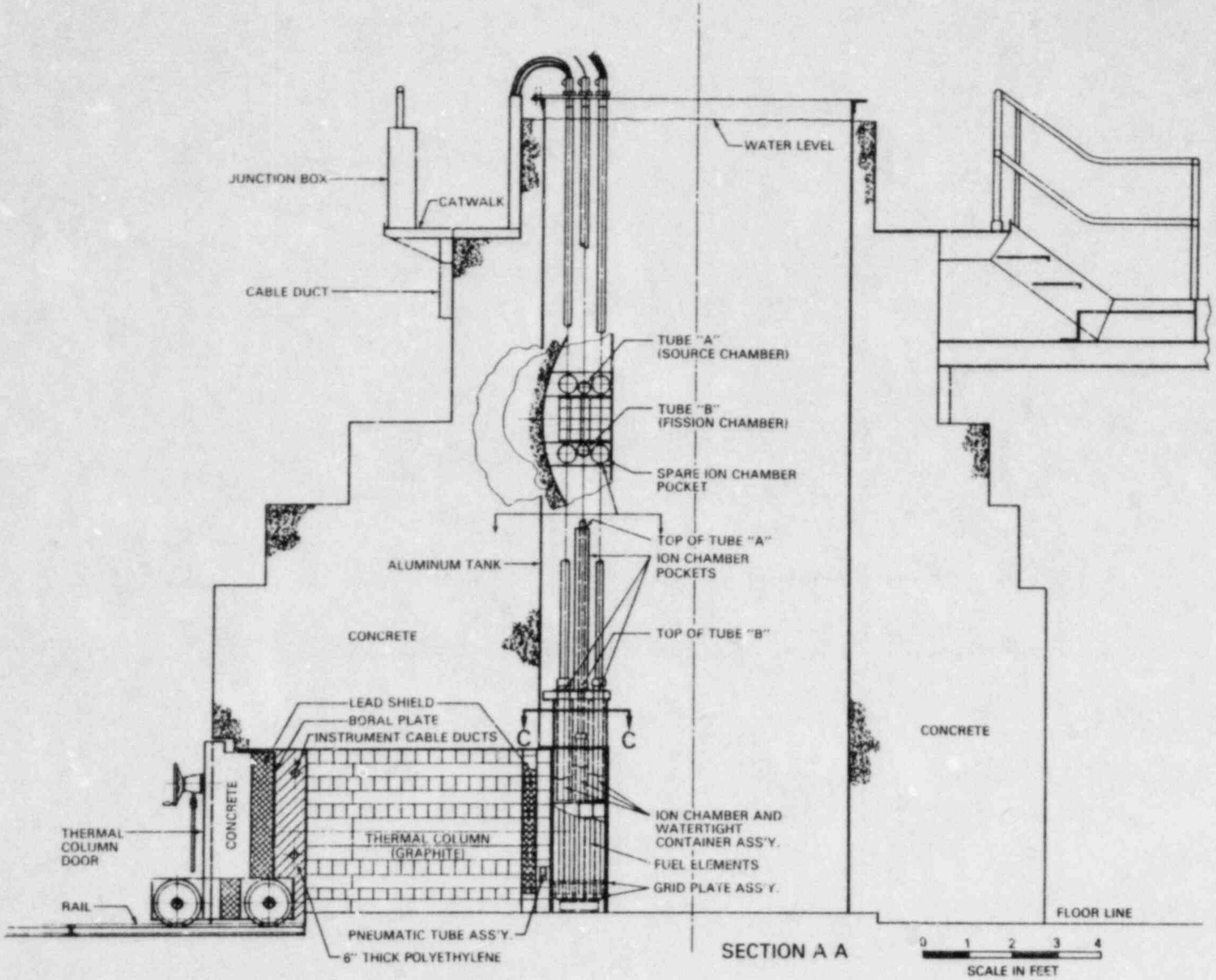

Figure 4.3 Front elevation of the reactor building
Source: License Application (Docket 50-148)

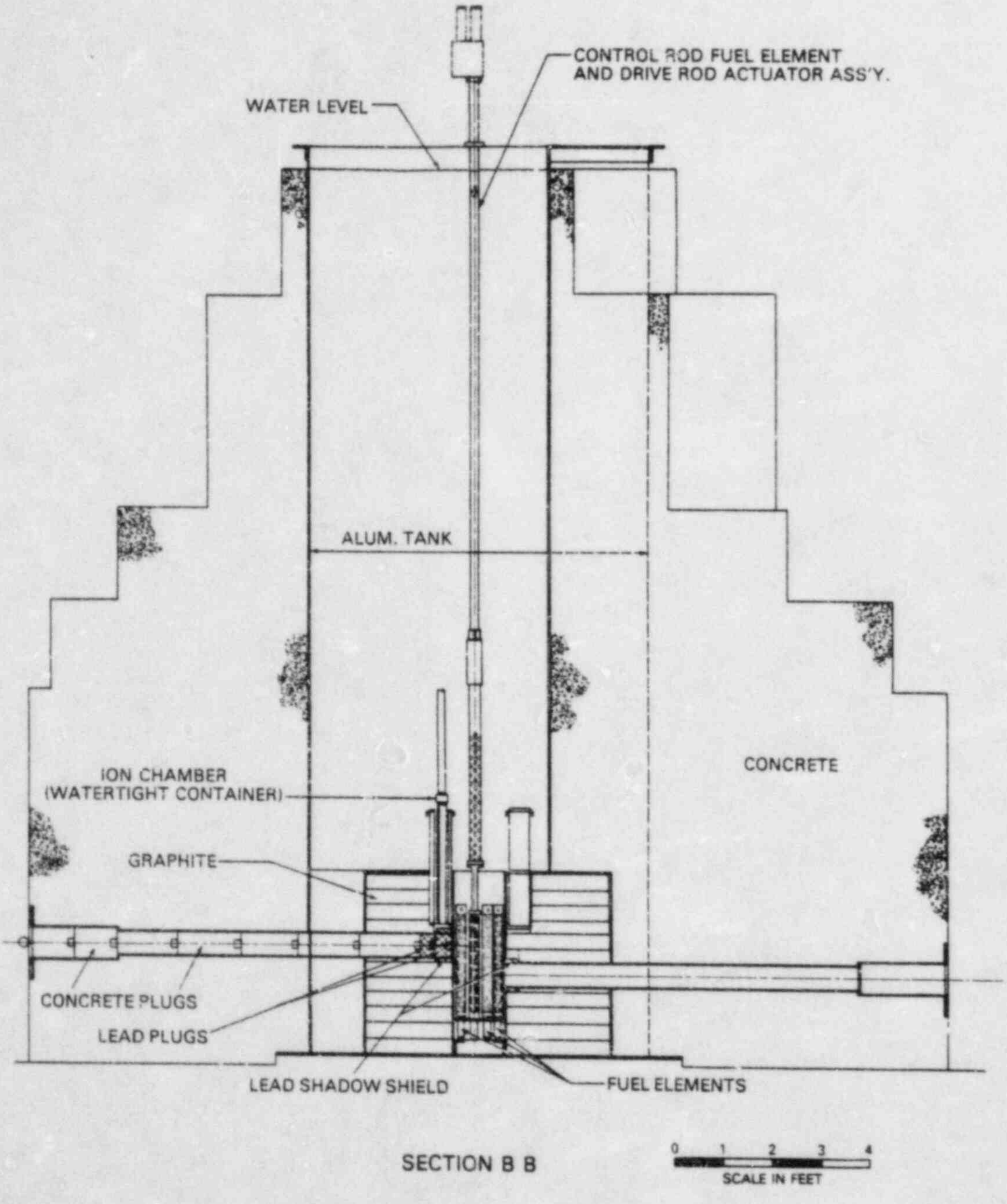

Figure 4.4 Side elevation of the reactor building
Source: License Application (Docket 50-148)

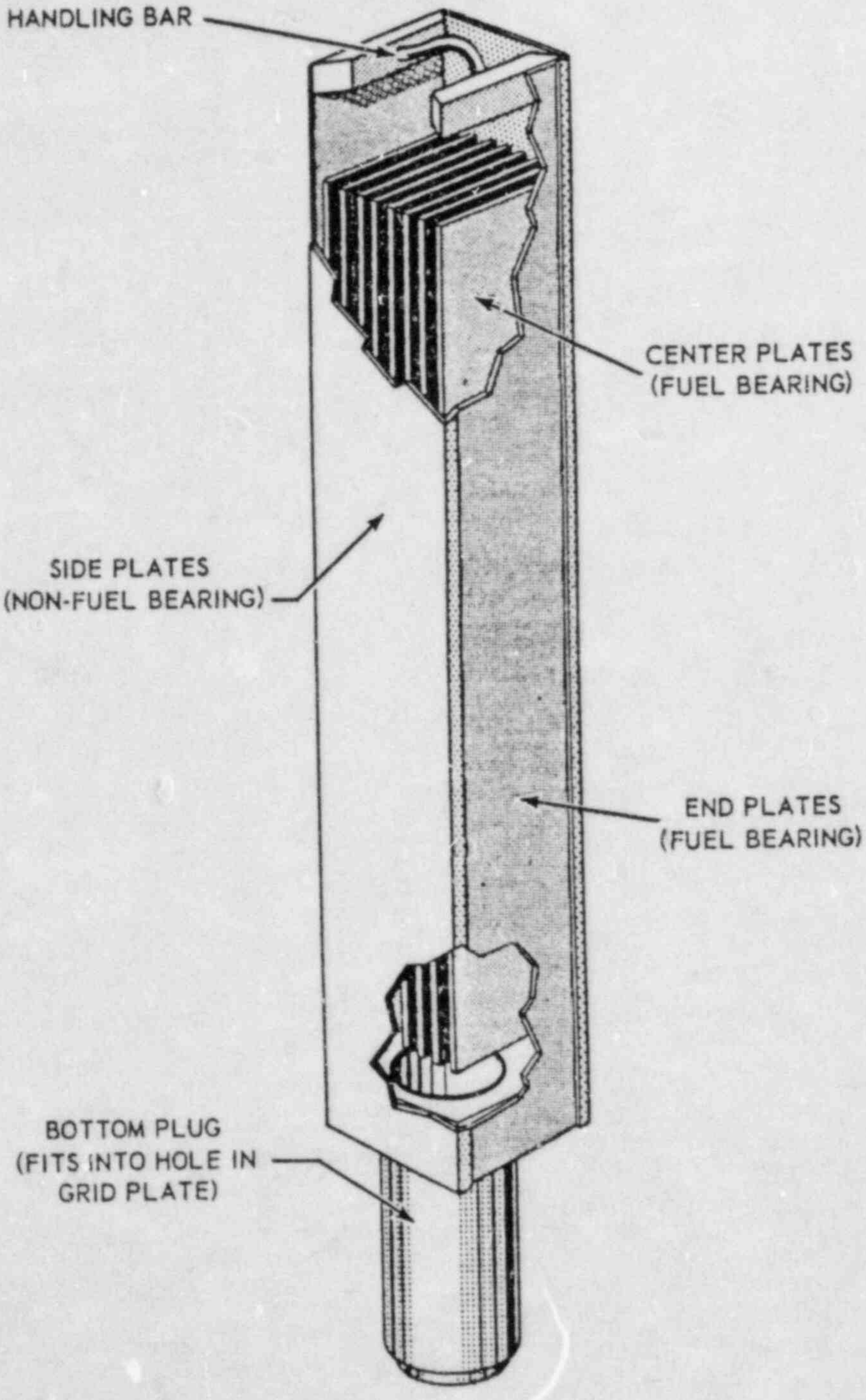

Figure 4.5 Reactor fuel element
Source: License Application (Docket 50-148)

Table 4.1 KUTR design and performance characteristics

Item	Characteristic
General Features	
Reactor type	Heterogenous - pool
Licensed rate power level	250kW
Excess reactivity (cold-clean)	1.5% $\Delta k/k$ maximum
Cold-clean critical mass	2.5 kg ^{235}U
Effective prompt neutron lifetime	90 μs
Effective delayed neutron fraction	0.0075
Average thermal flux at 250 kW	$2.5 \times 10^2 n/cm^2$-s
Moderator/coolant	H_2O
Reflector	Graphite on three sides; H_2O on one side, top and bottom
Fuel and Control Elements	
Number of fuel-bearing plates	
standard fuel elements	10
control rod fuel elements	5
Enrichment	93%
Maximum ^{235}U per fuel-bearing plate	17 g
Fuel Element Dimensions	
Fuel-bearing plate	
thickness	0.06 in.
width	3 in.
cladding	0.02 in.
Element	
cross-section	3 in. by 3 in.
length	35 in.
Control Rods and Reactivity Effects	
Material	Boral (35 w/o boron carbide)
Rods*	3
Travel	24.8 in.
Withdrawal speed	5 in./min
Rod worth	
Shim-safety rod	3.53 and 4.70% $\Delta k/k$
Shim-safety rods together	8.23% $\Delta k/k$
Regulating rod	1.99% $\Delta k/k$

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*Two of the rods are used as shim-safety rods and one is used as a regulating rod, although all three rods can be used as shim-safety rods.

Table 4.1 (Continued)

Item	Characteristic
Reactivity insertion rates (linear rates based on current core rod worths)	
Shim-safety rod	0.012 and 0.015% Δk/k/s
Shim-safety rods together	0.027% Δk/k/s
Regulating rod	0.007% Δk/k/s
Maximum reactivity insertion rate	
Single shim-safety rod	0.025% Δk/k/s
Two shim-safety rods	0.05% Δk/k/s
Maximum allowed rod drop time	1 s
<u>Coolant</u>	
Type	Light water
Flow	Natural convection
Pool temperature (maximum surface)	120°F
Conductivity (average over 1 month)	1 μmho/cm

5 REACTOR COOLANT COOLING AND PURIFICATION SYSTEM

5.1 Reactor Coolant Cooling and Purification System

The reactor core is submerged in demineralized water in a 6,600-gal aluminum tank and is cooled by natural convection. The Technical Specifications require that the reactor not be operated when the pool surface temperature is above 120°F. Reactor heat is removed from the pool water by conduction and convection to the environment. Even though there is a heat exchanger installed in the coolant cooling and purification loop, it has never been used.

About 3 gal/min of water are pumped from the pool through a filter, through a mixed-bed demineralizer, and back into the pool. The conductivity of the pool water is manually measured daily before reactor operations.

A siphon breaker is installed in the purification-loop return line near the pool surface so that a component failure cannot result in the pool water being siphoned.

A radiation monitor is installed adjacent to the demineralizer. The output from this instrument is displayed at the control console.

5.2 Conclusion

The system's cooling capacity is adequate to remove heat from the fuel and prevent overheating under all required operating conditions. The purification part of the system is adequate to maintain the coolant conductivity within the limit of the Technical Specifications thereby preventing corrosion of the aluminum fuel cladding and components in contact with the coolant. The system has been maintained effectively for the past 23 years. The staff concludes that there is reasonable assurance that the system can continue to function adequately.

6 ENGINEERED SAFETY FEATURES

Engineered safety features (ESFs) are systems provided to mitigate the radiological consequences of design-basis accidents. There are no ESF systems provided at the KUTR facility because none are deemed to be necessary.

The KUTR is a low-power (250 kW) pool-type reactor. The licensee's Technical Specifications limit full-power operation to 750 kW hours followed by a recovery period of such duration that the power averaged from the beginning of the run, including shutdown periods, will be less than 10 kW. The reactor may be operated at power levels up to 10 kW during the recovery period. Therefore, the fission product inventory is very low. In addition, the analyses of accidents in Section 14, including the maximum hypothetical accident, indicate that there will be no release of radioactive material to the environment.

The staff concludes that the KUTR, without any ESF systems, does not pose a radiological hazard to the public or to the environment in the event of an accident.

7 CONTROL AND INSTRUMENTATION

The control and instrumentation systems at the KUTR are similar to those in wide use for similar research reactors in the United States. Control of the nuclear fission process is achieved by using three control rods. The instrumentation system, which is interlocked with the control system, is composed of both nuclear and process instrumentation. The control and instrumentation systems are summarized in Table 7.1.

7.1 Control System

The control system is composed of both nuclear and process control equipment in which safety-related components are designed for redundant operation in case of single failure or malfunction of components essential to the safe operation or shutdown of the reactor.

7.1.1 Nuclear Control Systems

Control of the reactor is achieved in the standard way by inserting and withdrawing neutron-absorbing control rods by the use of control drive units mounted on the superstructure over the pool. The three control rods are supported by electromagnets so that any electrical power interruption will result in the rods falling by gravity into slots in the core, causing a reactor scram. The control rod drives are controlled from the control center by the reactor operator. The control rod system is discussed in more detail in Section 4.2.2.

7.1.2 Supplementary Control Systems

These control systems, which are designated as process control systems, are designed to control the various processes involved in reactor operation but do not directly relate to safety. Included in this category are circuits and devices that energize and/or monitor the pump and coolant parameters such as temperature and conductivity.

7.2 Instrumentation System

The instrumentation system is composed of both nuclear control and process instrumentation circuits. The electronics system contains both solid-state and tube-type components and provides annunciation and/or indication in the control room. Automatic scram function is provided through the safety amplifier (discussed below).

7.2.1 Nuclear Instrumentation

The following instrumentation (see Figure 7.1) provides the operator with the necessary information for proper manipulation of the nuclear controls.

(1) Log count rate or startup channel - This channel receives data from a movable fission chamber. Its primary purpose is to monitor reactor power during startup.

(2) Linear-N power or linear power channel - This channel receives data from a compensated ion chamber. This channel monitors the reactor power level in the range of 0.25 W to greater than 250 kW and provides the signal for automatic servocontrol of reactor power.

(3) Log-N power channel - This channel also receives data from a compensated ion chamber and monitors the reactor power level from a 0.25 W to greater than 250 kW. This channel also provides the signal to the period amplifier for indication of the reactor period.

(4) Safety channel - An uncompensated ion chamber provides the signal, which gives the redundancy to scram the reactor in response to abnormally high power.

All neutron-sensing ion chambers are located in the reactor tank outside of the core and are independently adjustable over a limited distance to allow calibration of their respective channels to the reactor thermal power derived from thermal calibration of pool temperature rise and/or cobalt flux foils.

7.2.2 Reactor Safety System

The reactor safety and instrumentation systems are interconnected through a safety amplifier. This unit provides current for the electromagnets that support the control rods. The safety circuit provides for either a fast scram by directly decreasing the dc current in the holding magnets or a slow scram by interrupting the ac power supply to the magnets.

7.2.3 Inhibits and Annunciation

Inhibit signals that will prevent control rod removal (reactor startup) are provided by low neutron count rate in the startup channel and if the period is less than 20 sec or if the log count rate meter and log N amplifer switch are not in the operate position.

A control-console-mounted pilot light/annunciator panel provides the operator with information on conditions of important variables related to reactor operation. The annunciator is energized continuously through the main power disconnect switch. Following annunciation of an event, the conditions must be corrected and the operator must reset to restore the annunciator to its normal operating condition. The conditions indicated by this panel are

(1) Indicated conditions

Line power on
Rods at upper or lower limit of travel
Rods seated
Rods in contact with their respective magnets
Magnet power supply on
Water circulating pump on
Manual or servocontrol of regulating rod

(2) Annunciated and indicated conditions

Rod withdrawal bus off
Rod insertion
Area radiation alarm
Scram

7.3 Supplementary Instrumentation

Additional process instrumentation consists of the facility radiation monitoring systems.

Fixed area monitors, provided in the reactor bay, include one on the east wall, one on the south wall, one on the west wall near the demineralizer, and one above the reactor tank. These monitors provide exposure rate indication and alarm at the control center. The west wall monitor provides an indication of the radioactivity in the coolant cleanup demineralizer. Abnormal conditions, such as a failed experiment or a leaking fuel element, would cause an increase in the radiation level associated with the demineralizer.

An air monitor is used periodically to determine the radioactivity level of the air in the reactor bay area. In addition, the reactor bay area is monitored continuously if the evaluation of an experiment shows that 25% of the allowable exposure, as defined Table I, Appendix B of 10 CFR 20, can be exceeded in the event of an accident.

7.4 Conclusions

The control and instrumentation systems at the KUTR are well designed and maintained. Redundancy in the important ranges of power measurements is ensured by overlapping ranges of the log-N and linear power channels.

The licensee's performance specifications for the individual components used throughout the system are satisfactory. This helps to ensure system reliability and decreases the chances of serious simultaneous multicomponent failures.

The control system is designed so that the reactor is automatically and safely shut down if electrical power is lost.

On the basis of its review of the control and instrumentation systems, the staff has concluded that these systems are adequate to ensure continued safe operation of the reactor within the context of the Technical Specifications.

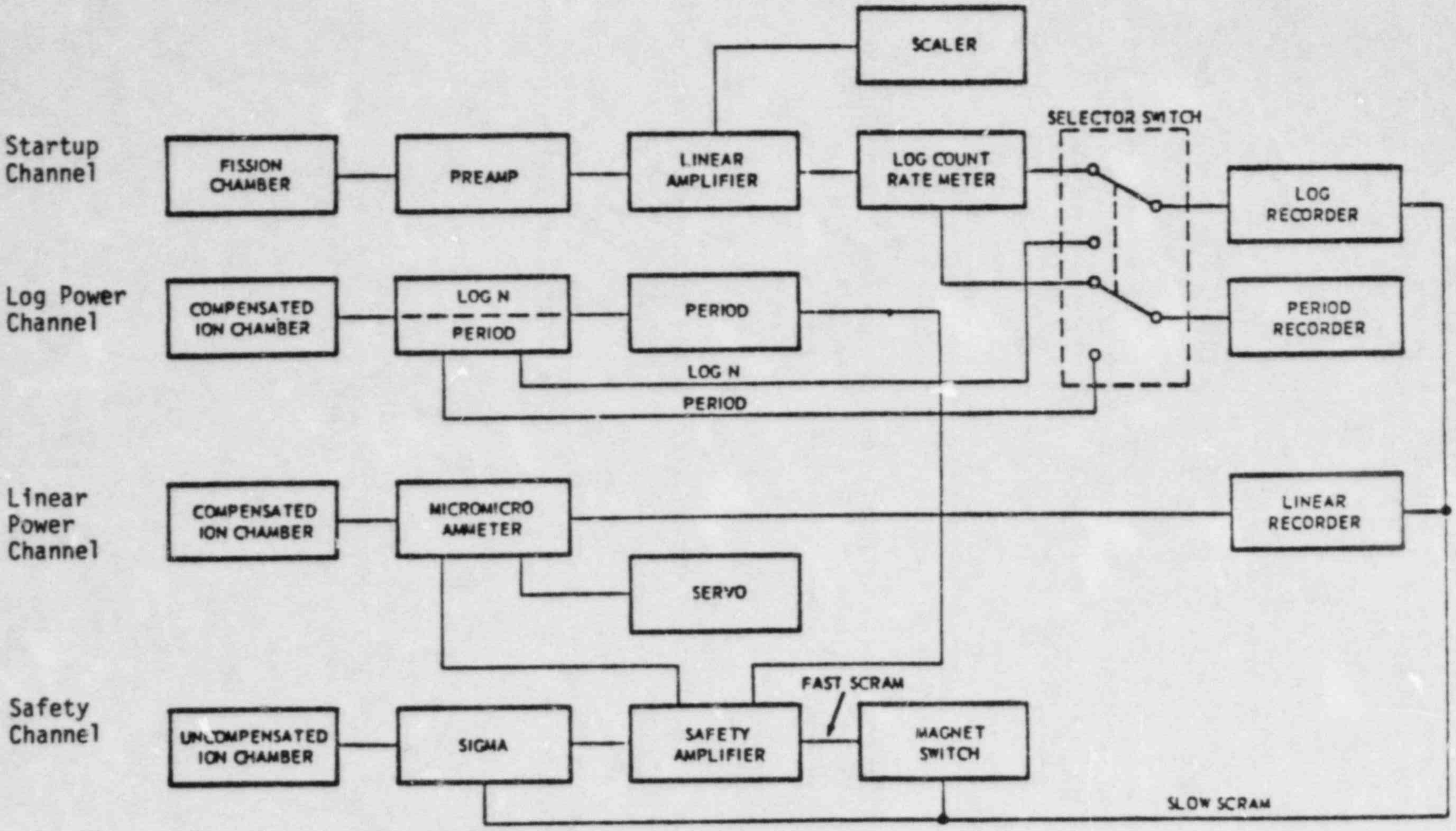

Figure 7.1 Schematic of nuclear instrumentation

Table 7.1 Safety and control instrumentation

Channel	Minimum number operating	Function	Set point	Modes in which required
Log count rate	1	Indication	Count rate <2 cps	
		Inhibit		Startup
Linear power	1	Indication		
		Scram	>125% of scale reading	All
		Reversal	>110% of scale reading	
Log N power	1	Indication		
		Scram	>150%	All
Log N amplifier	-	Inhibit	Not in operate position	All
Period	1	Indication		All
		Scram	<2 s	
		Reverse	<10 s	
		Inhibit	<20 s	
Power safety	1	Indication		
		Scram	>125%	All
Manual scram	1	Scram		All
Sigma amplifier (safety power circuit)	1	Scram	Amplifier failure	All
High voltage loss to linear power chamber	1	Scram		All
Magnet power key switch	1	Scram		All
Core outlet temperature	1	Indication	>120°F	All
Regulating rod position	1	Indication		
		Reversal	Lower limit of travel	
Servodeviation (regulating rod only)	1	Indication		Servo-control
		Automatic transfer to manual	±25% of power	

Table 7.1 (Continued)

Channel	Minimum number operating	Function	Set point	Modes in which required
Radiation monitors	(2 of 4)*	Indication Alarm		All*
East wall			10 mR/h at 10 kW and 100 mR/h at 250 kW	
South wall			10 mR/h at 10 kW and 100 mR/h at 250 kW	
West wall (demineralizer)			10 mR/h at 10 kW and 100 mR/h at 250 kW	
Reactor tank (above)			10 mR/h at 10 kW and at 250 kW	

*If less than 2 fixed monitors are operative, reactor operation at power levels $\leq$10 kW are permissible using enough portable gamma sensitive monitors to provide the required two channels, provided their operation is verified and the radiation levels and locations are recorded in the log books.

8 ELECTRIC POWER SYSTEM

8.1 Normal AC Power

Kansas Power and Light Company provides two feeder lines to the University of Kansas campus; the feeder lines terminate at the transformer stations. The station supplying the reactor facility and nearby buildings is located next to the reactor building.

The main breaker on the distribution panel in the reactor building basement supplies the three circuits that make up the 208-V and 100-V loads of the facility.

8.2 Emergency Power

There are no provisions for emergency power at the KUTR facility.

8.3 Conclusion

The staff concludes that the KUTR electrical system is adequate for the safe operation of the facility and that emergency electrical capability is unnecessary because loss of all electrical power causes a reactor scram with no need for decay heat removal.

9 AUXILIARY SYSTEMS

9.1 Fuel Handling and Storage

Reactor fuel is not handled routinely. If it is necessary to rearrange fuel elements in the core, a long-handled manual tool is used. If it is necessary to remove a fuel element, the storage pool is first filled by using hoses to siphon a portion of the reactor pool water into it. The fuel element then is pulled up into a shielded cask. The cask then is moved by the overhead crane to the storage pool, where it is removed from the cask and placed in a fuel storage rack at the bottom of the storage pool. KU has two unirradiated spare fuel elements that are stored in a dry locked vault in the reactor building.

9.2 Air Conditioning and Ventilation System

An air conditioning unit installed in the reactor room heats or cools room air for human comfort and electronic component longevity. Compressed-air-operated dampers at the unit blower inlet provide for the desired mixing of outside air and recirculated air. To protect the environment from radiation contamination, administrative procedures instruct the reactor operator to shut off the ventilation blower in case of a radioactivity release.

9.3 Compressed Air System

There are two air compressors installed in the reactor building: one unit supplies the air to operate air conditioning system dampers, the other supplies the compressed air needs of the various laboratories in the building.

9.4 Fire Protection System

Fire protection is provided by a portable fire extinguisher in the reactor bay area. There are several fire extinguishers in the other section of the reactor building. A building fire alarm is initiated manually. Fire fighting capability is provided by the Lawrence Fire Department.

9.5 Conclusion

The fuel-handling and storage system design is adequate to ensure that reactor fuel can be moved, serviced, and stored without danger to operating personnel or the public because of radioactivity of the fuel or a possible accidental criticality event.

The facility's compressed air system, ventilation system, and fire protection system are designed to adequately service the facility under normal and emergency conditions that may occur.

On the basis of the above, the staff concludes that the KUTR auxiliary systems are adequate to ensure continued safe operation of the facility.

10 EXPERIMENTAL USES

The KUTR is used for various experimental programs in addition to its function as a training tool. The experimental programs use the reactor as a source of ionizing and neutron radiation for research and for isotope production. The experimental facilities include a pneumatic exposure facility, a thermal column, four beam ports, and a bulk-shielding facility. Except for the bulk-shielding facility, all these facilities are outside the reactor tank and within the graphite assembly around the tank.

10.1 Experimental Facilities

10.1.1 Pneumatic Exposure Facility

A pneumatic exposure facility allows small, sealed samples to be transferred rapidly between the reactor and the reactor room. The irradiation terminus is within the graphite assembly; the receiver terminus is a location just outside the reactor shield. The controls for the pneumatic transfer system are located near the outer terminus. The driving force for this system is pressurized carbon dioxide gas. The exhaust gases from the system are released to the reactor room through a high-efficiency filter.

10.1.2 Beam Ports

There are four 6-in diameter beam ports, that approach the reactor core on two sides. These tubes terminate within the graphite assembly at the tank wall, and, therefore, do not penetrate the reactor vessel. These tubes normally are filled with shielding material. The shielding materials may be removed to provide external beams of radiation through the beam ports and/or to insert samples for irradiation.

10.1.3 Thermal Column

The thermal column is a graphite assembly located on the south side of the reactor tank. The graphite assembly consists of 4 in. by 4 in. graphite blocks of various lengths assembled into a 4 ft by 5 ft by 6 ft configuration. There are 20 horizontal stringers that may be removed in sections of different lengths to form experimental holes of various sizes.

During reactor operation, the thermal column is shielded by a movable door. The shielding material on the door is comprised of 6 in. of polyethylene near the graphite assembly, followed by a 1/4-in.-thick Boral plate and 1-ft-thick concrete in a steel frame.

10.1.4 Bulk Shielding Facility

The bulk-shielding facility is the 7.5-ft-diameter and 20-ft-high reactor tank filled with water. This facility is occasionally used for material irradiations in a fast neutron flux.

10.2 Experimental Review

All new experiments and classes of experiments that could affect the reactivity or result in the release of radioactive material are reviewed by the Nuclear Reactor Committee. The membership of the Nuclear Reactor Committee is designed to provide a spectrum of expertise to review the experiments and their potential hazards. This review and approval process for experiments allows personnel trained in reactor operations to consider and suggest alternative operational conditions and irradiation times that will minimize personnel exposure and/or potential release of radioactive materials to the environment. Approved experiments are carried out in accordance with established procedures and within the limitations prescribed in the Technical Specifications.

10.3 Conclusion

The staff concludes that the design of the experimental facilities, combined with the detailed review and administrative procedures applied to all research activities, is adequate to ensure that the experiments are (1) not likely to fail, (2) not likely to release significant radioactivity to the environment, and (3) not likely to cause damage to the reactor system or its fuel. Therefore, the staff concludes that reasonable provisions have been made so that the experimental programs and facilities do not pose a significant risk to the facility staff and the public.

11 RADIOACTIVE WASTE MANAGEMENT

The major radioactive waste generated by reactor operations is activated gases, principally ^{16}N and ^{41}Ar. A limited volume of radioactive solid waste is generated by reactor operations, and some additional solid waste is produced by the associated research programs. The facility regenerates the coolant purification ion exchanger resin beds; thus, the wastes from coolant purification end up in the liquid waste streams from the facility. Because of the limited use of the reactor, very little wastes are generated at this facility.

11.1 ALARA Commitment

The KUTR is operated with the philosophy of minimizing the release of radioactive materials to the environment. The university administration, through the Radiation Safety Officer, instructs all operating and research personnel to develop procedures to limit the generation and subsequent release of radioactive materials to comply with the as-low-as-is-reasonably-achievable (ALARA) commitment.

11.2 Waste Generation and Handling Procedures

11.2.1 Solid Waste

The generation of high-level radioactive waste in the form of spent fuel is not anticipated during the term of this license renewal. Therefore, the only solid waste generated as a result of reactor operations consists of air and coolant filters, potentially contaminated paper and gloves, and occasional small activated components. Some of the reactor-based research results in the generation of solid low-level radioactive wastes in the form of contaminated paper, gloves, and glassware. This solid waste is held temporarily at the site before being packaged and shipped to an approved disposal site in accordance with applicable regulations.

11.2.2 Liquid Waste

Normal reactor operations produce no radioactive liquid waste other than the coolant with small amounts of tritium and waterborne activation products. The coolant cooling and purification system is adequate to purify this coolant on a continuous basis. There is a 500-gal liquid waste holdup tank to collect all the liquids from the regeneration of ion exchange resins of the coolant cooling and purification system and from other parts of the reactor facility. The hot laboratory is equipped with a floor drain that leads to this liquid waste holdup tank. The pool overflow also drains into this holdup tank. The radioactive nuclides in the liquid wastes are generally allowed to decay before the liquid waste is released to the city sewer system. Before releasing the liquid waste to city sewer lines, it is monitored to determine the radioactivity levels. If the concentrations of the radioactive material in the tank are less than the levels specified in 10 CFR 20, the contents are discharged to the city sewer system. If the concentrations are initially above 10 CFR 20 limits, the contents of the tank are stored for decay or diluted below the 10 CFR 20 levels before discharge.

11.2.3 Airborne Waste

The potential airborne waste is composed of ^{41}Ar, ^{16}N, and neutron-activated dust particulates. These are produced by the irradiation of air and airborne particulates in the thermal column and the beam ports. The concentrations of airborne ^{41}Ar, ^{16}N are well below the limits prescribed by 10 CFR 20. No fission products escape from the fuel cladding during normal operations. Both the licensee's and staff's evaluations show that the release of airborne radioactivity from the reactor facility at the University of Kansas would lead to exposures in the unrestricted areas that are well within the limits specified in 10 CFR 20.

11.3 Conclusion

The staff concludes that the waste management activities at the KUTR facility have been conducted and are expected to continue to be conducted in a manner consistent with 10 CFR 20 and with the ALARA principles. Among other guidance, the staff review has followed the methods of ANSI/ANS 15.11, "Radiological Control at Research Reactor Facilities," 1977.

Because ^{41}Ar is the only significant radionuclide released by the reactor to the environment during normal operations, the staff has reviewed the history, current practices, and future expectations of operations. The staff's calculations show that the doses in unrestricted areas as a result of actual releases of ^{41}Ar have never exceeded or even approached the limits specified in 10 CFR 20 when averaged over a year.

12 RADIATION PROTECTION PROGRAM

The University of Kansas has a structured radiation safety program with a health physics staff equipped with radiation detection instrumentation to determine, control, and document occupational and radiation exposures at its reactor facility.

12.1 ALARA Commitment

The University of Kansas, through its Radiation Safety Service, has established for the campus the policy of minimizing all radiation exposures to ALARA. All proposed experiments and procedures at the reactor are reviewed for ways to minimize potential exposures to personnel. All unanticipated or unusual reactor-related exposures will be investigated by both the Radiation Safety Officer and the operations staff to develop methods to prevent recurrences.

12.2 Health Physics Program

12.2.1 Health Physics Staffing

The normal radiation safety staff at the University of Kansas consists of two professional health physicists and one student technician. The routine health-physics-type activities at the reactor are performed by the operations staff. The health physics staff is available for consultation and the university Radiation Safety Officer is a member of the Nuclear Reactor Committee. The health physics office is located on the second floor of the KUTR facility and is readily accessible to all personnel and reactor users.

12.2.2 Procedures

Detailed written procedures have been prepared that address the radiation safety support and emergency procedures for the university's research reactor facility. These procedures identify the interactions between the operational personnel and facility users. They also specify the administrative limits and action points. Copies of these procedures are readily available to the operational and research staffs and to administrative and staff personnel.

12.2.3 Instrumentation

KU has a variety of instruments, including portable monitors, for detecting and measuring potentially hazardous ionizing radiations. The instrument calibration procedures and techniques ensure that any credible type of radiation and its intensity will be identified 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 safety instructions are given to those who will be working with radiation or radioactive materials. The training program is designed to identify hazards and to mitigate their consequences. Reactor operators are given an examination on radiation safety once every 2 years and retraining in radiation safety is provided depending on the performance of reactor operators during these examinations.

12.3 Radiation Sources

12.3.1 Reactor Sources

Sources of radiation directly related to the reactor operations include the reactor core, the ion exchange column, the filters for the water cleanup system, and radioactive gases (primarily ^{41}Ar and ^{16}N). Radiation exposures from the reactor core are reduced to acceptable levels by water, graphite, and concrete shielding. The ion exchange column is periodically regenerated, and the filters are changed regularly to minimize the radiation level from these sources. Personnel exposure to radiations from ^{41}Ar and ^{16}N is extremely limited because of the small quantities of these isotopes and the dilution of the gases by the air.

12.3.2 Extraneous Sources

Sources of radiation that may be considered as incidental to the normal reactor operation but associated with reactor use include radioactive isotopes produced for research, activated components of experiments, and activated samples. Personnel exposure to radiation from intentionally produced radioactive materials, 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.

12.4 Routine Monitoring

12.4.1 Fixed-Position Monitors

The KUTR has four fixed-position radiation monitors: one above the reactor tank and one each on the east, west, and south walls of the reactor. The fixed-position monitor on the west wall is near the demineralizer unit for the reactor coolant. Two of the monitors, one on the south wall and one on the east wall, are usually set at 10 mR/hour as the alarm set point. These may be out of service when the reactor is not operated above a 10-kW power level. The other two fixed-position monitors are operational during all reactor operations. However, portable monitors may be used at power levels < 10 kW within the defined limits of the Technical Specifications. For operations between 10 and 250 kW, the alarm set points for these two fixed-position detectors are 100 mR/hour, whereas they are set at 10 mR/hour for operations below 10 kW. All the monitors have adjustable alarm set points and read out in the control room.

12.4.2 Experimental Support

The health physics staff participates in experiment planning by reviewing all proposed procedures for minimizing personnel exposures and limiting the generation of radioactive wastes. Approved procedures specify the type and degree of radiation safety support required by each activity.

12.5 Occupational Radiation Exposures

12.5.1 Personnel Monitoring Program

The KU personnel monitoring program is described in the licensee's "Radiation Safety Service Standard Procedures." Personnel exposures are measured by the use of film badges assigned to individuals who might be exposed to radiation. Self-reading pocket ion chambers are used for short-term visitors to the facility. Administrative controls are used to keep the exposure limits within 10 CFR 20 guidelines.

12.5.2 Personnel Exposures

The annual radiation exposure history of the personnel at the KUTR facility is summarized in Table 12.1.

12.6 Effluent Monitoring

12.6.1 Airborne Effluents

As discussed in Section 11 of this SER, the airborne effluents from the reactor facility consist principally of very low concentrations of ^{41}Ar. The ^{16}N (with a half-life of 7.4 sec) hardly leaves the reactor building in any detectable levels. The small amount of ^{41}Ar released to the reactor room is diluted by almost 18,300 ft^3 of air. The calculated concentration of ^{41}Ar in the reactor bay after 3 hours of operation at 250 kW will be on the order of 2.5×10^{-6} µCi/ml. This specific concentration will exist only for brief periods and only in the event that the exhaust system was not operational. In actual operation, this concentration is never achieved.

12.6.2 Liquid Effluents

The reactor generates very limited radioactive liquid waste during routine operations. The primary source of liquid waste is during the regeneration of the ion exchangers used in the coolant cleanup system. Also, leakage of the reactor coolant is a potential source of radioactive liquid effluent. All floor drains in the reactor bay lead to the liquid waste holdup tank. Before any release of potentially contaminated liquids from this holdup tank to the sanitary sewer system, representative samples are collected and analyzed by standard techniques. If the concentrations of radionuclides in the liquid waste are less than the guideline values of 10 CFR 20.303, the liquids are discharged directly to the sewer system.

12.7 Environmental Monitoring

There is an environmental monitoring program at the KUTR facility. The airborne radioactivity observed has never exceeded 10^{-11} µCi/ml among the more than 200 samples collected during the period of 1973 through 1979.

12.8 Potential Dose Assessment

Natural background levels of radiation in the Lawrence, Kansas, area result in the exposure of 100 mrems/year to each individual residing in that area

(Klement et al., 1972). At least an additional 10 mrems/year will be received by those living in a brick or masonry structure. Any medical diagnosis X-ray examination will add to this natural background radiation, increasing the total annual exposure. On the basis of the amount of ^{41}Ar released during normal operations from the KUTR facility, conservative calculations by the staff predict a maximum annual exposure of less than 1 mrem in the unrestricted areas.

12.9 Conclusions

The staff concludes that the radiation protection program at KU receives adequate support from the university administration. The staff also concludes that (1) the radiation safety support is acceptable for the research efforts within this reactor facility, (2) the program is adequately staffed and equipped, (3) the health physics staff has adequate authority and lines of communication, (4) the procedures are properly integrated into the research plans, and (5) surveys verify that operations and procedures achieve ALARA principles.

The staff concludes that the effluent monitoring programs conducted at the KUTR facility are acceptable to promptly identify significant release of radioactivity and to predict maximum exposures to individuals in the unrestricted areas. The predicted maximum levels are well within applicable regulations and guidelines of 10 CFR 20. The staff considers that there is reasonable assurance that the personnel and procedures will continue to protect the health and safety of the public.

Table 12.1 Number of individuals monitored in exposure intervals

	Number of individuals in each range				
Whole body exposure range (rem)	1979	1980	1981	1982	1983
No measurable exposure	1	6	5	6	3
Measurable exposure					
<0.1 rem	9	0	0	1	5
0.1 to 0.25 rem	0	0	0	0	0
Number of individuals monitored	10	6	5	7	8

13 CONDUCT OF OPERATIONS

13.1 Organizational Structure and Qualifications

13.1.1 Overall Organization

Responsibility for the safe operation of the reactor facility lies within the organizational structure shown in Figure 13.1. Management level personnel, in addition to having responsibility for the policies and operation of the reactor facility, are responsible for safeguarding the public and facility personnel from radiation exposures and for adhering to all requirements of the OL and Technical Specifications.

13.1.2 Reactor Staff

The reactor facility staff consists of two engineering school faculty members; a combined operator and maintenance man, part-time student operators and a health physicist.

13.2 Training

The licensee operator requalification plan has been reviewed by the NRC staff, which finds that it meets the requirements of 10 CFR 50.34(b)(7) and (8).

13.3 Emergency Planning

In accordance with 10 CFR 50.54(q) and (r) requirements, the licensee submitted an updated Emergency Plan on September 26, 1983. The Plan was reviewed against the requirements of Appendix E to 10 CFR 50. In addition, the review extended to ascertaining the degree of conformance with the guidance criteria set forth in Revision 1 to Regulatory Guide 2.6 and ANSI/ANS 15.16-1982, "Emergency Planning for Research Reactors." On the basis that the Emergency Plan provides reasonable assurance that protective actions can and will be taken in response to radiological emergencies occurring at the KUTR, the staff concludes that the KUTR Emergency Plan meets established requirements and is acceptable.

13.4 Operational Review and Audit

The KU Nuclear Reactor Committee reviews and approves new experients and proposed alterations to the reactor. The committee reviews and audits reactor operations for safety. It is composed of the Reactor Director and the Radiation Safety Officer and three other members having expertise in radiation technology.

The committee reviews

(1) proposed changes in equipment, systems, tests, experiments, or procedures to determine that they do not involve an unreviewed safety question

(2) all new procedures and major revisions having safety significance, proposed changes in reactor facility equipment, or systems having safety significance

(3) tests and experiments in accordance with requirements in the Technical Specifications

(4) proposed changes in Technical Specifications, license or Charter

(5) violations of Technical Specifications, license, or Charter; Violations of procedures or instructions having safety significance, as well as remedial actions to ascertain that the violations do not recur

(6) operating abnormalities having safety significance and audit reports

(7) reportable occurrences listed in the Technical Specifications

The committee also has audit functions that include selective (but comprehensive) examination of operating records, logs, and other documents.

13.5 Facility Procedures

The applicant has committed to the development and maintenance of procedures that are appropriate for continued safe operation. The current procedures are documented and filed within the reactor facility.

13.6 Physical Security

KU has established and maintained a program designed to protect the reactor and its fuel and to ensure its security. The staff has reviewed the plan and concludes that the plan, as amended, meets the current requirements of 10 CFR 73.67 for special nuclear materials of moderate strategic significance. KU's licensed authorization for reactor fuel 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) and 10 CFR 9.5(a)(4). Amendment 12 to the facility OL R-78 dated February 23, 1982, incorporated the physical security plan as a condition of the license.

13.7 Conclusion

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

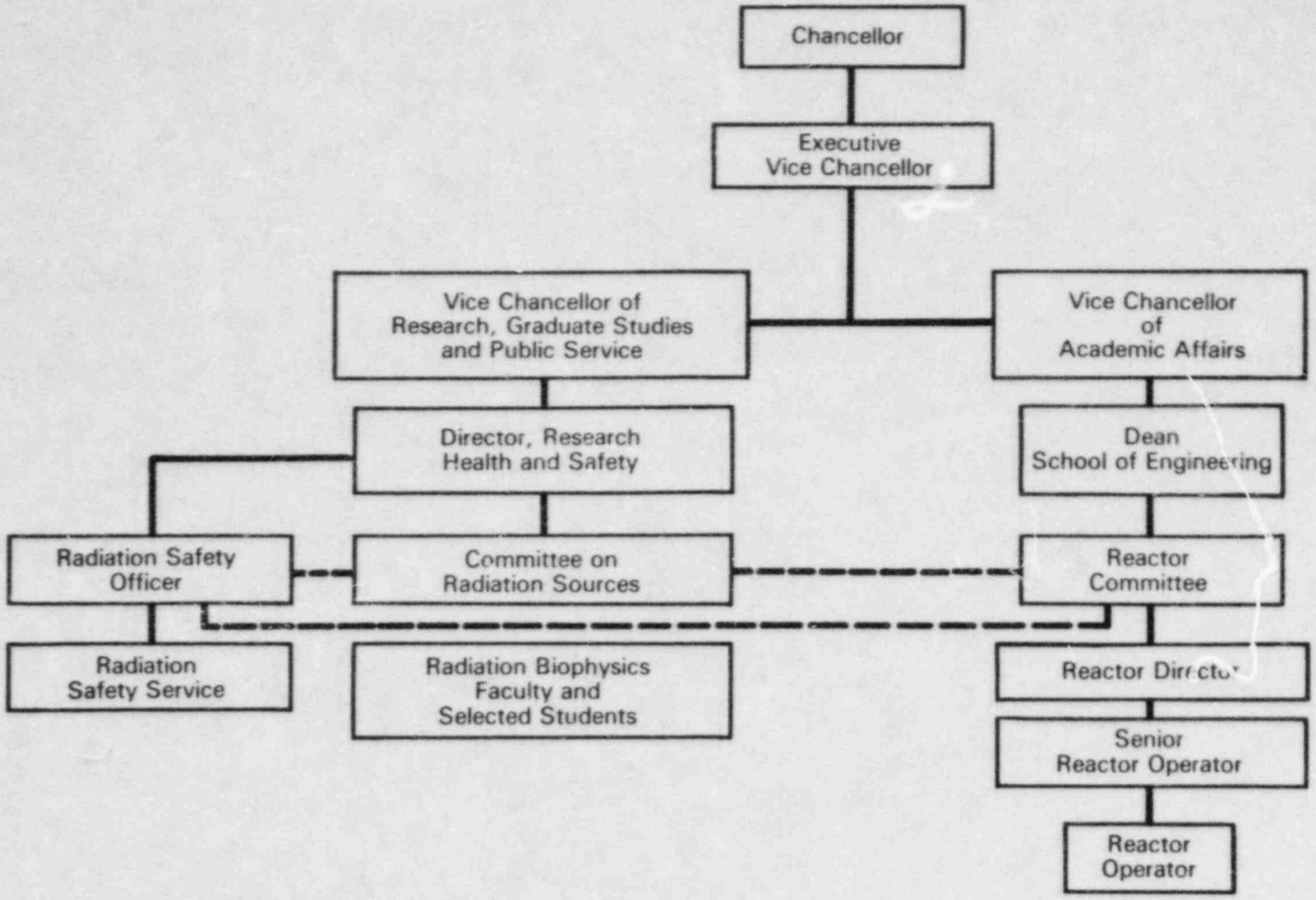

Figure 13.1 University of Kansas reactor facility organizational structure

14 ACCIDENT ANALYSIS

In establishing the limiting safety system settings and the limiting conditions for operation for the KUTR Technical Specifications, the licensee analyzed potential transients to ensure that these events would not result in the safety limits being exceeded. Hypothetical accidents and their effects on the core and the health and safety of the public also were analyzed. In addition, the staff has independently analyzed several potential transients and hypothetical accidents.

No credible reactor transient or accident scenario could be postulated for the KUTR by either the licensee or the staff that would pose a significant risk of fuel cladding failure and that would result in a release of radioactivity. The postulated event with the greatest potential effect on the reactor facility is a step reactivity insertion equivalent to the maximum allowed excess reactivity. The step reactivity insertion transient is designated for the KUTR as the maximum hypothetical accident (MHA). An MHA is defined as an accident for which the potential risk is greater than any other credible event. Thus, the staff assumes that the accident occurs, but does not try to describe or evaluate the mechanical details of the accident or the probability of its occurrence. Only the consequences are evaluated.

14.1 Excess Reactivity Insertion

As mentioned above, a rapid, large reactivity insertion has been defined as the MHA for this reactor. The maximum power excursion (transient) that could occur would be one resulting from the inadvertent rapid insertion of the total available excess reactivity. The KUTR fuel loading is limited by its Technical Specifications to a total excess reactivity of 1.5% $\Delta k/k$. The licensee has analyzed the effect of step reactivity insertions. The analysis is based on the results of the BORAX experiments (Dietrich 1954) and uses the analysis method of Edlund and Norderer (1957).* The licensee has calculated the temperature rise resulting from step reactivity insertions ranging from 1.0 to 2.0% $\Delta k/k$ for a pool-type reactor with a 18 ft water head (distance from center of core to the water surface) and an initial temperature of 68°F. The calculated fuel-plate temperature rises for step reactivity insertions between 1.0% $\Delta k/k$ are as follows:

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*The BORAX and SPERT experiments investigated the effects of reactivity insertions on reactors using MTR (plate) type fuel elements; thus, the results of these experiments are applicable to other reactors using similar fuel. The effects of both step and ramp reactivity insertions were investigated and both the BORAX and SPERT experiments were concluded with destructive step reactivity insertions (Dietrich, 1954; Neyer, 1956; Zeissler, 1963; Miller et al., 1974; Crocker and Stephan, 1964; and Smith, 1981).

Step reactivity insertion (% Δk/k)	Fuel plate temperature rise (F°)
1.0	315
1.25	549
1.5	936
1.75	1,458
2.0	2,668

The calculated temperature rise from a 1.5% Δk/k step insertion results in a fuel temperature of 1,004°F (936+68), which is well below the melting point of aluminum (1,220°F). The licensee's analysis concludes that the step insertion of the allowed total excess reactivity would not result in fuel melting and subsequent release of radioactivity. The staff agrees with this concluson and notes that the results of both the BORAX and SPERT experiments (Dietrich, 1954; Nyer, 1956) demonstrated that no mechanical damage to MTR-type fuel elements would be caused by a rapid reactivity insertion of 1.5% Δk/k. The staff further notes that the calculational method used by the licensee indicates that a reactivity insertion of about 1.65% Δk/k would be required to result in a fuel temperature of about 1,200°F with potential melting of the fuel cladding.

On the basis the above considerations, the staff concludes that a nuclear excursion caused by a step reactivity insertion equivalent to the maximum allowed excess reactivity for the KUTR would not exceed the safety limits for the fuel. Therefore, there is reasonable assurance that fission product activity would not be released from the fuel to the environment as a result of an excess reactivity insertion event.

14.2 Loss of Coolant

The licensee analyzed a loss-of-coolant accident as part of the safety analysis in support of the application for a license amendment (granted in 1971) to increase the KUTR maximum power level from 10 to 250 kW. The analysis assumes (1) complete loss of coolant immediately following operation at 250 kW for 3 hours, (2) shutdown caused by loss of moderator, and (3) only air cooling of the fuel. The Technical Specifications limit individual runs at power levels above 10 kW to an integrated energy of 750 kW hours, followed by a recovery period of such duration that the power averaged from the beginning of the run, including shutdown periods, will be less than 10 kW.

The energy released in the first hour after the loss of coolant was calculated by the licensee to be 1,370 W-hours. The fuel temperature rise resulting from this energy release is about 130°F, assuming that the elements are perfectly insulated. The licensee further indicated that the calculated rate of energy release after 1 hour was 700 W and that this could be dissipated to the air. The staff has calculated the energy release for the time period from 1 hour to 4 hours after the loss of coolant accident, based on a release rate of 700 W at the beginning of the time period. The energy releases and the fuel temperatures rises, assuming the elements are perfectly insulated, are given as follows:

Time period	Energy release (W-hours)	Fuel temperature rise (°F)
1 to 2 hours	530	50
2 to 3 hours	192	18
3 to 4 hours	23	2

The total fuel temperature rise in the first 4 hours after the loss-of-coolant accident, assuming perfect insulation, would be 200°F, which is well below the fuel cladding melting point (1,220°F). The rate of temperature rise after 4 hours is negligible.

The licensee concluded, on the basis of his analysis, that the loss of coolant would not result in fuel melting and subsequent release of fission products to the environment. The staff's 1971 evaluation agreed with the licensee's conclusion. In its current review, the staff also has calculated the fuel temperature rise for up to 4 hours after the loss of coolant.

On the basis of the information presented above, the staff concludes that a loss-of-coolant accident will not result in fuel melting and subsequent release of fission products, even if steps are not taken to reflood the reactor after the loss of coolant.

14.3 Experimental Facility Accidents

Experimental facility accidents may be considered in the context of the excess reactivity insertion transient analyzed in Section 14.1. The analysis indicates that a step reactivity insertion of 1.5% $\Delta k/k$ would not result in mechanical damage to the fuel or temperatures approaching the melting point of the fuel cladding. The licensee's Technical Specifications limit the total absolute excess reactivity of all experiments in the reactor and the associated experimental facilities to 1.5% $\Delta k/k$ with a further limitation on the total absolute worth of movable experiments of 1.2% $\Delta k/k$. Thus, the staff concludes that there is no credible accident involving experiments that could lead to fuel melting and subsequent release of fission product radioactivity to the environment.

14.4 Maximum Startup Accident

In this accident it is assumed that all rods are withdrawn simultaneously. It is further assumed that no protective action is taken until the high-power scram is tripped automatically. This presumes failure of the period and power reversals and the period scram. In essence, the accident results in a ramp reactivity insertion that is terminated by the high-power scram. The effects of ramp reactivity insertions on pool-type reactors were investigated in the SPERT experiments (Forbes, 1956). The ramp insertion experiments conducted at ambient temperature with a 2-ft water head demonstrated that a total reactivity insertion of up to 2.5% $\Delta k/k$ at insertion rates up to 0.35% $\Delta k/k$ per second did not cause damage to the reactor, although divergent oscillations appeared toward the end of the run. Additional tests with an insertion rate of 0.09% $\Delta k/k$ per second, a water head of 9 ft, and total reactivity insertions up to 2.5% $\Delta k/k$ yielded results substantially the same as those for the 2-ft water head. The oscillations observed in these tests were relatively long-term effects.

Both the licensee and the staff have evaluated the results of the SPERT experiments with respect to the KUTR. Based on the shim-safety and regulating rod worths in the current core of 10.22% Δk/k (4.70 +3.53 +1.99), a drive speed of 5 in./min and a travel of 24.8 in., the insertion rate would be 0.034 Δk/k per second. This insertion rate assumes a linear rod worth. Assuming a 50% increase in insertion rate at the point of maximum rod effectiveness, the insertion rate could be as much as 0.05% Δk/k per second. Both insertion rates are well below the insertion rate of 0.35% Δk/k per second, which the SPERT experiments demonstrated did not result in damage to the core. The reactivity insertion would be terminated by a high-power scram within 5 to 10 seconds of the accident, thereby limiting the total reactivity insertion to less than 0.34 or 0.5% Δk/k for insertion rates of 0.034 and 0.05% Δk/k per second, respectively. Because the divergent power oscillations are a long-term phenomenon, there is sufficient time for operator intervention; however, such intervention would not be required unless all the high-power scrams, the period scram, and period and high-power reversals failed.

On the basis of the above considerations, the staff concludes that the nuclear excursion caused by the postulated maximum startup accident would not result in damage to the reactor core or components. Therefore, there is reasonable assurance that fission product radioactivity will not be released from the fuel as a result of a ramp reactivity insertion event.

14.5 Fuel Handling Accidents

The staff has considered two fuel handling accidents at the KUTR. These are the dropping of a single element during fuel manipulations and the dropping of a shielding cask during the transfer of fuel to the fuel storage pool.

The tool used for moving fuel elements is designed to provide a positive lock on the fuel element handling bar (Figure 4.1). Improper latching of the tool could result in dropping of the element. The resulting damage to the element could cause sufficient mechanical distortion to prohibit continued use of the element; however, sufficient damage to strip cladding from one or more fuel-bearing plates with subsequent release of fission products is not credible.

The staff has analyzed an accident in which a fuel element is dropped during fuel manipulation so that it occupies a position on the periphery of the core. Because fuel manipulation is done with all rods fully inserted, a nuclear excursion would not occur unless the element has a worth greater than that of the three rods less the maximum allowed excess reactivity (for the current core, -10.22 +1.5= -8.72% Δk/k). Typically, the worth of an element in a peripheral position will be less than 2% Δk/k. Thus, a reactivity insertion accident because of fuel element mishandling is not credible. The staff further notes that in a typical fuel manipulation operation the first fuel movement is from the core to the in-pool fuel storage racks, thus reducing the core reactivity.

During in-pool operations involving a fuel transfer cask, the potential for dropping the cask exists. The staff has considered such an accident and concludes that the core supporting structure that suspends the core assembly from the bridge and the control rod drives would serve as a protective barrier between the falling cask and the fuel elements. These structures would absorb most of the energy of the falling cask, thereby limiting damage to the fuel elements to mechanical distortion. Although considerable mechanical damage of the reactor structures, control rods, and fuel elements could occur, failure of fuel cladding and subsequent release of fission products is not considered credible because the fuel is essentially integral with the cladding and because there is no gap in which gaseous fission products are accumulated and subject to release upon a breach of cladding.

The staff concludes, on the basis of the above considerations, that fuel handling accidents will not lead to release of fission products to the reactor building or the environment because of fuel cladding failures. The staff further notes that because of the limited operating schedule of the KUTR, the fuel element fission product inventory is quite low; thus, even if a cladding failure was credible, the resulting release of radioactivity would be minimal.

14.6 Conclusion

On the basis of its review, the staff concludes that no credible accidents or transients are postulated that can result in the release of significant quantities of fission products to the unrestricted environment. Therefore, the staff concludes that the design of the facility together with the Technical Specifications provides reasonable assurance that the KUTR can be operated at power levels of 250 kW without significant risk to the health and safety of the general public or the KUTR staff and students.

15 TECHNICAL SPECIFICATIONS

The Technical Specifications define certain features, characteristics, and conditions governing the continued operation of the KUTR facility. The Technical Specifications will be made a part of the renewed operating license. The Technical Specifications follow the most recent industry guidance, American Nuclear Society Standard 15.1, "Standard for the Development of Technical Specifications for Research Reactors."

On the basis of its review, the staff concludes that normal plant operation within the limits of the Technical Specifications will not result in offsite exposures in excess of the 10 CFR 20 limits.

16 FINANCIAL QUALIFICATIONS

In support of the license renewal application, KU supplied financial information that described sources of funds necessary to cover the estimated cost of operation plus the estimated costs of permanently shutting down the facility and maintaining it in a safe condition. The staff reviewed the financial information supplied by the licensee in the application and concluded that KU possesses or can obtain the necessary funds to meet the requirements of 10 CFR 50.33(f). Therefore, the staff concludes that the licensee is financially qualified to continue to operate the reactor.

17 OTHER LICENSE CONSIDERATIONS

17.1 Prior Reactor Utilization

The previous sections concluded that only a postulated MHA accident of a large step reactivity insertion would result in a significant fuel temperature increase. This still would not lead to failure of the fuel cladding and the consequent release of fission products. As explained in previous sections, the design of the reactor, and the low-power level and part-time use of the reactor preclude serious consequences from any postulated accident.

The staff considered the effects of the past 23 years of reactor use on continued safe operation of the facility. Significant factors that minimize the effect of past use are

(1) The operators of the KUTR perform regular preventive maintenance to discover potential failures or to preclude the failure of components. 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 preventive maintenance program would lead to adequate identification and replacement before failure occurs.

(2) Startup procedures that check critical components also evaluate component performance before reactor operation. Inoperative components are attended to before starting reactor operation. This is the procedure that has been followed since the reactor first received its OL in 1961.

(3) The corrosion of the aluminum cladding is expected to be negligible because high purity of the reactor coolant is maintained by the coolant cooling and purification system.

(4) The in-core reactor fuel elements are handled as infrequently as possible. Any indications of possible damage or degradation are investigated immediately consistent with periodic surveillance. Therefore, the staff concludes that loss of integrity of cladding through damage does not constitute a significant risk to the public.

(5) The Technical Specifications are performance specifications and are not predicated on the age of the components. If a component does not meet the requirements of its particular specification, the reactor is not permitted to operate until the specification requirement is satisfied.

17.2 Conclusion

On the basis of the above discussion, the staff concludes that the KUTR is operated under conditions that are conservatively below the safety limits of its components, and that surveillance and maintenance procedures give reasonable assurance that continued operation will pose no significant radiological risk to the health and safety of 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 the operating license for the University of Kansas training and research reactor, dated March 4, 1980, as amended, 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 1.

(2) The facility will operate in conformity with the application as amended, 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 1.

(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 1.

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

19 REFERENCES

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

---, ANSI/ANS 15.11, "Radiological Control at Research Reactor Facilities," 1977.

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

---, ANS 15.16, "Standard for Emergency Planning for Research Reactors," Draft - 1978 and Draft 2 - November 29, 1981.

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

Crocker, J. G., and L. A. Stephen, "Reactor Power Excursion Tests in the SPERT IV Facility," Idaho Operations Office Report IDO-17000, August 1964.

Dietrich, J. R., "Experimental Investigation of the Self-Limitation of Power During Transients in a Sub-Cooled Water-Moderated Reactor, BORAX-1 Experiments," Argonne National Laboratory, Report AECD-3668, 1954.

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

Forbes, S. G., F. Schroeder, and W. E. Nyer, "Instability in the SPERT-1 Reactor, Preliminary Report," Idaho Operations Office, Report IDO-16309, October 10, 1956.

Klement, A. W., Jr., C. R. Miller, R. P. Minx, and B. Schleien, "Estimates of Ionizing Radiation Doses in the United States 1960-2000," U.S. Environmental Agency, Report ORP/CSD72-1, August 1972.

Miller, R. W., A. Sola, R. K. McCardell, "Report on the SPERT I Destructive Test Program on an Aluminum, Plate-Type, Water Moderated Reactor," Idaho Operations Office Report IDO-16883, June 1974.

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

Smith, R. R., "Radiological Consequences of BORAX/SPERT/SNAPTRAN Experiments," Nuclear Technology, Vol. 53, pp. 147-154, May 1981.

U.S. Nuclear Regulatory Commission, NUREG/CR-3117, "Seismicity and Tectonic Relationships of the Nehama Uplift and Midcontinent Geophysical Anomally," R. R. Burchett, K. V. Luza, O. J. Van Eck, and F. W. Wilson, p. 33, February 1983.

---, Regulatory Guide 2.6, "Emergency Planning for Research Reactors," 1979, For Comment, and Rev. 1, March 1982.

Wood, H. O., and F. Newman, "Modified Mercalli Intensity Scale of 1931," Seismic Society of America Bulletin, Vol. 21, pp. 277-283, 1931.

Zeissler, M. R., "Non-destructive and Destructive Transient Tests of SPERT I-D, Fully Enriched, Aluminum-Plate-Type Core: Data Summary Report," Idaho Operations Office Report IDO-16886, November 27, 1963.

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This Safety Evaluation Report for the application filed by the University of Kansas (KU) for a renewal of Operating License R-78 to continue to operate the KU 250-kw open-pool training 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 Kansas and is located on the KU campus in Lawrence, Douglas County, Kansas. The staff concludes that the reactor facility can continue to be operated by KU without endangering the health and safety of the public.

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