NUREG-1083

Safety Evaluation Report

related to the renewal of the operating license for the Westinghouse research reactor at Zion, Illinois

Docket No. 50-87

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

September 1984

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ABSTRACT

This Safety Evaluation Report, for the application filed by the Westinghouse Electric Company, for renewal of operating license number R-119 to continue to operate the research reactor, has been prepared by the Office of Nuclear Reactor Regulation of the U.S. Nuclear Regultory Commission. The facility is operated by Westinghouse and is located in Zion, Illinois. The staff concludes that the reactor facility can continue to be operated by Westinghouse without endangering the health and safety of the public.

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1 INTRODUCTION

By letter dated December 18, 1981, to the U.S. Nuclear Regulatory Commission (NRC/staff), the Westinghouse Electric Corporation (licensee) submitted an application for renewal for a period of 10 years of their Class 104 Operating License R-119 for operation of the Westinghouse Nuclear Training Reactor (WNTR) located at Zion, Illinois. A letter dated January 5, 1982, revising the renewal application, requested that the term of the license period be revised to 20 years. The renewal application is supported by information provided in the Safety Analysis Report dated December 1981 and the proposed Technical Specifications dated December 1981, as amended.

The WNTR has a 10-kW, highly enriched uranium, light-water cooled, and graphite moderated and reflected core. The primary use of the reactor facility is in support of nuclear training programs. The reactor is used to conduct demonstrations and to provide operating experience for Westinghouse customer personnel in the areas of fundamental reactor physics and reactor operations. Other minor activities include irradiation experiments and reactor instrumentation studies.

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

The purpose of this Safety Evaluation Report (SER) is to summarize the results of the safety review of the WNTR 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 WNTR facility at thermal power levels up to and including 10 kWt. The facility was reviewed against the requirements of 10 CFR 20, 30, 50, 51, 55, 70, and 73; applicable regulatory guides (RGs) (Division 2, Research and Test Reactor); and appropriate accepted industry standards (American National Standards Institute/American Nuclear Society (ANSI/ANS) 15 Series). Because there are no accident-related regulations for nonpower reactors, the staff has compared calculated dose values with related standards in 10 CFR 20, the standards for protection against radiation for employees and the public.

The staff safety review with respect to issuing an operating license renewal to WNTR has been based on the information contained in the renewal application and supporting supplements, generic studies performed by independent national laboratories, site visits, and responses to requests for additional information. This material is available for review at the NRC Public Document Room at 1717 H Street, N.W., Washington, D.C.

Major contributors to the technical review include the NRC project manager and J. Hyder, A. Pope, A. Crawford, and C. Linder of the staff from the Los Alamos National Laboratory (LANL). This SER was prepared by H. Bernard, Project Manager, Standardization and Special Projects Branch, Division of Licensing, Office of Nuclear Reactor Regulation, Nuclear Regulatory Commission.

1.1 Summary and Conclusions of Principal Safety Considerations

The staff evaluation considered the information submitted by the licensee, past operating history recorded in annual reports submitted to the Commission by the licensee, reports by the Commission's Office of Inspection and Enforcement, and onsite observations. In addition, as part of the licensing review, the staff obtained independent national laboratory studies and analyses of several severe hypothetical accidents postulated for the WNTR. The principal safety matters reviewed for the WNTR and the conclusions reached follow:

(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 a broad spectrum of postulated credible accidents have been considered, emphasizing those likely to cause loss of integrity of fuel-element cladding. The staff performed conservative analyses of the most serious credible accidents and determined that the calculated potential radiation doses outside of the reactor building are small fractions of 10 CFR 20 guidelines for persons in unrestricted areas.

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

(4) The systems, provided for control of radiological effluents, can be operated to ensure that releases of radioactive wastes from the facility are within the limits of 10 CFR 20 and are as low as is reasonably achievable (ALARA).

(5) The licensee's Technical Specifications, which provide limiting conditions for the 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 WNTR facility is funded within the annual budget requests of the Westinghouse Electric Corporation. The staff agrees that sufficient funds will be available for the safe operation of the reactor facility.

(7) The licensee's program for providing for the physical protection of the facility and its special nuclear material complies with the applicable requirements in 10 CFR 73.67.

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

(9) The WNTR Emergency Plan was submitted as part of the original license renewal application and subsequently amended by letter and report dated October 29, 1982, as part of the current NRC requirements that were published in the Federal Register (47 FR 88) on May 6, 1982. The staff reviewed the plan and found it to be acceptable (see Section 13.6).

1.2 History

In January 1972, the Westinghouse Electric Company was granted Operating License R-119 for the nuclear training reactor to operate at a power level not in excess of 10 kWt. The reactor reached criticality in February 1972 and operated at 10 kWt soon thereafter. However, most of the operations since then have been at power levels of much less than 10 kWt. Total thermal power produced from 1972-1983, is approximately 400 kW hours.

1.3 Reactor Facility Description

The WNTR is located in the south wing of the Westinghouse Nuclear Training Center (NTC), and the training center is located approximately 2,400 ft from the Commonwealth Edison Company's Zion Nuclear Power Station (see Figures 1.1 and 1.2). The Westinghouse/Zion site is on the west shore of Lake Michigan, approximately 40 mi north of Chicago, Illinois, and 42 mi south of Milwaukee, Wisconsin.

The reactor has a highly enriched uranium-aluminum alloy core that is light-water cooled and moderated and graphite moderated and reflected. The fuel consists of the uranium-aluminum alloy contained in an aluminum tube. A standard fuel element includes three concentric fuel tubes with the fuel meat occupying 36 in. of a 47 5/16 in. assembly. The reactor core consists of 19 standard fuel elements and five control rod elements. A more detailed description of the core and its components is provided in Section 4.

1.4 Design and Facility Modifications

Except for a major change in core configuration, the WNTR is, in essence, the same as when originally licensed in 1972. To reduce the quantity of uranium below a "formula quantity," the core was redesigned in 1981 to operate with 24 fuel and control elements instead of the 37 it contained. Reducing the core in the above manner was not an unresolved safety question, as was shown by calculations and experiments that verified the safety analysis performed by Westinghouse. This was further verified by the NRC staff. Therefore, in accordance with 10 CFR 50.59, Westinghouse, in 1981, reduced the number of fuel elements in the core to 24. WNTR has been operating with that configuration ever since.

1.5 Shared Facilities and Equipment

All the utilities and services provided in the Nuclear Training Center (NTC) building are used for both the reactor facility (located in the south wing) and the other training facilities. These include power reactor simulations, laboratories, computer rooms, and offices. However, the reactor facility has its own dedicated exhaust system.

1.6 Comparison With Other Facilities

Although the WNTR is a unique design, the fuel technology of uranium-aluminum alloy fuel, clad with aluminum, is used extensively in research reactors both in the United States and abroad. Considerable experience is available with the use of this type of fuel.

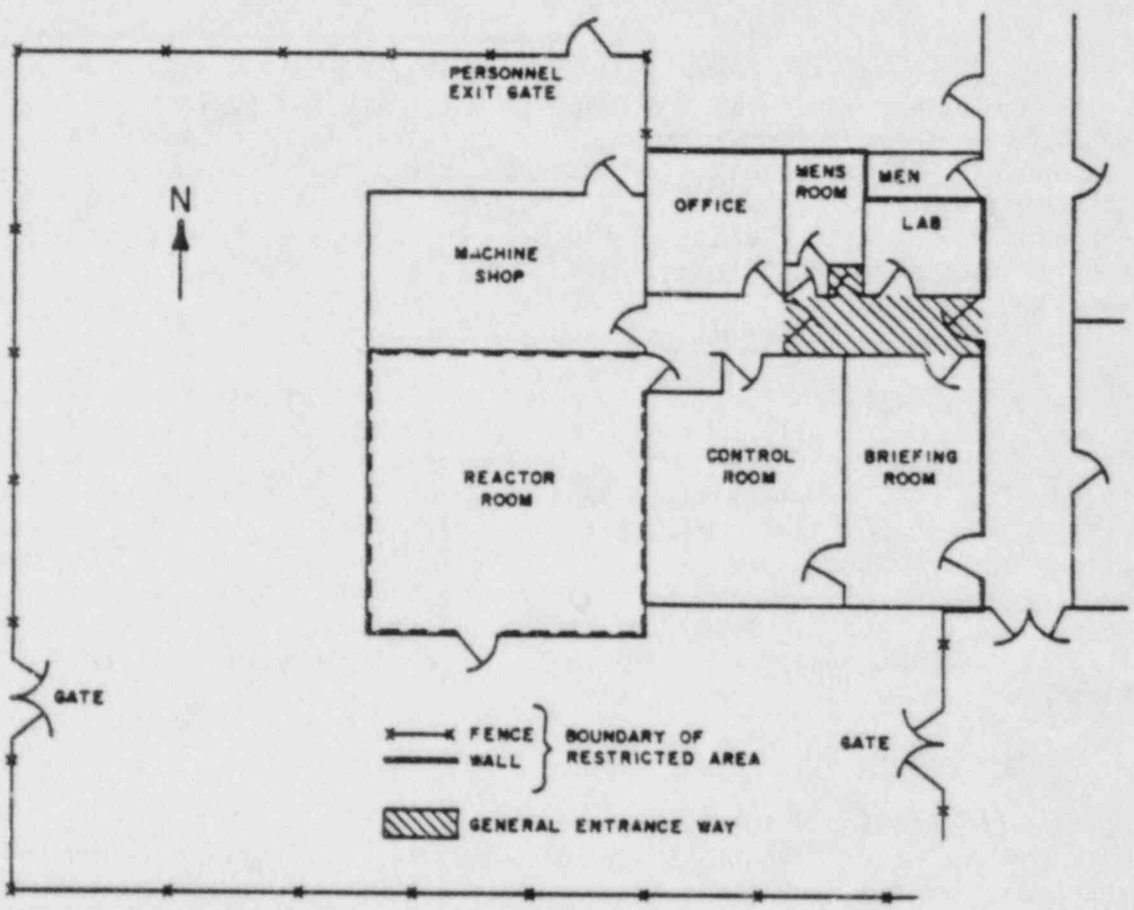

Figure 1.1 Westinghouse nuclear training reactor location in the Nuclear Training Center building

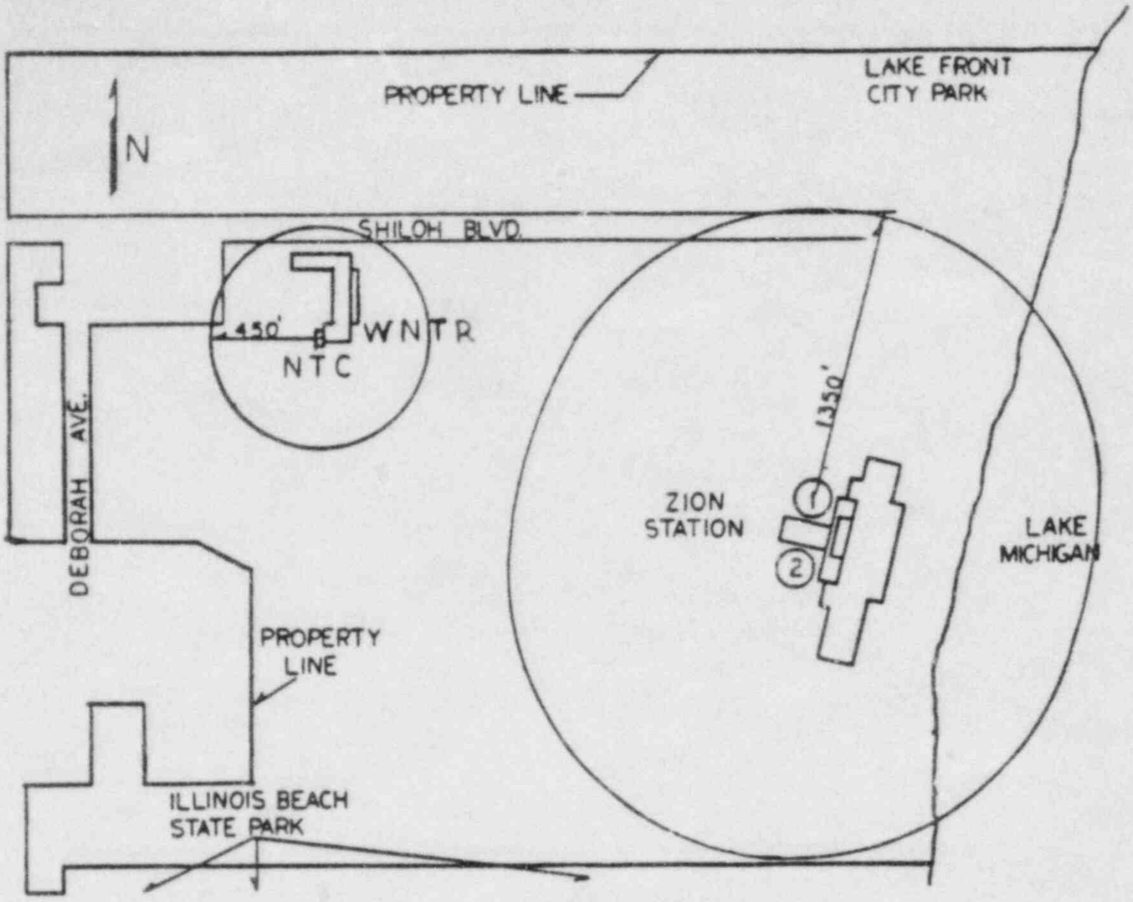

Figure 1.2 Zion Nuclear Power Station site layout

1.7 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. By letter dated May 3, 1983, DOE informed the NRC that it has a contract with Westinghouse Electric Company, which provides that DOE is obligated to take the spent fuel and/or high-level waste for storage or reprocessing. It is determined, therefore, that Westinghouse is in conformance with the Waste Policy Act of 1982.

2 SITE CHARACTERISTICS

The WNTR facility is located approximately 2,400 ft from the Zion Station, adjacent to the Zion exclusion area as shown in Figure 1.2. The proximity of the two facilities makes the Zion site data valid for the WNTR site in almost every detail. Accordingly, the site and environmental information presented by the applicant was largely based on that information presented in the Zion Preliminary Safety Analysis Report (PSAR) (Docket Nos. 50-295 and 50-304).

2.1 Geography and Topography

The site, comprising approximately 250 acres, is located in the extreme eastern portion of the city of Zion, Lake County, Illinois, on the west shore of Lake Michigan, approximately 6 mi NNE of the center of the city of Waukegan, Illinois, and 8 mi south of the center of the city of Kenosha, Wisconsin. In the vicinity of the reactor site, Lake County is a small industrial region with extensive agriculture interspersed and predominating west of the city of Zion. The Illinois State Beach Park, immediately to the south of the site, maintains picnic and camping areas. Within the park site, approximately 1 mi south of the WNTR site, there is also a 100-room motel, which is used year round. The lake shore north of the site is little used during the summer months because of the marshy nature of that region.

The site is traversed from west to east by Shiloh Boulevard near the northern property boundary (see Figure 1.2). Figure 2.1 shows the general region within a 5-mi radius of the site.

The topography of the WNTR site and its immediate environs is relatively flat with a mean elevation of approximately 586 ft, which is 6 ft above the level of the lake. Approximately 2 mi west of Lake Michigan there is a topographical divide causing surface water drainage west of the divide to be away from the lake, while to the east drainage is toward the lake. The site itself has very little slope and is relatively marshy.

2.2 Population Distribution

Waukegan, Illinois, is the nearest population center, other than Zion; the distance to the closest boundary is approximately 3.6 mi.

On the basis of the U.S. Census Bureau 1980 data and on past trends in populations and probable future industrial, commercial, residential and recreational developments, the total projected population of Lake County, Illinois, is 669,000 in 1985 and 2,000,000 in 2000. Seasonal population increases, as a result of summer cottage occupants in the vicinity of the site, are minimal and primarily to the north along the lake shore.

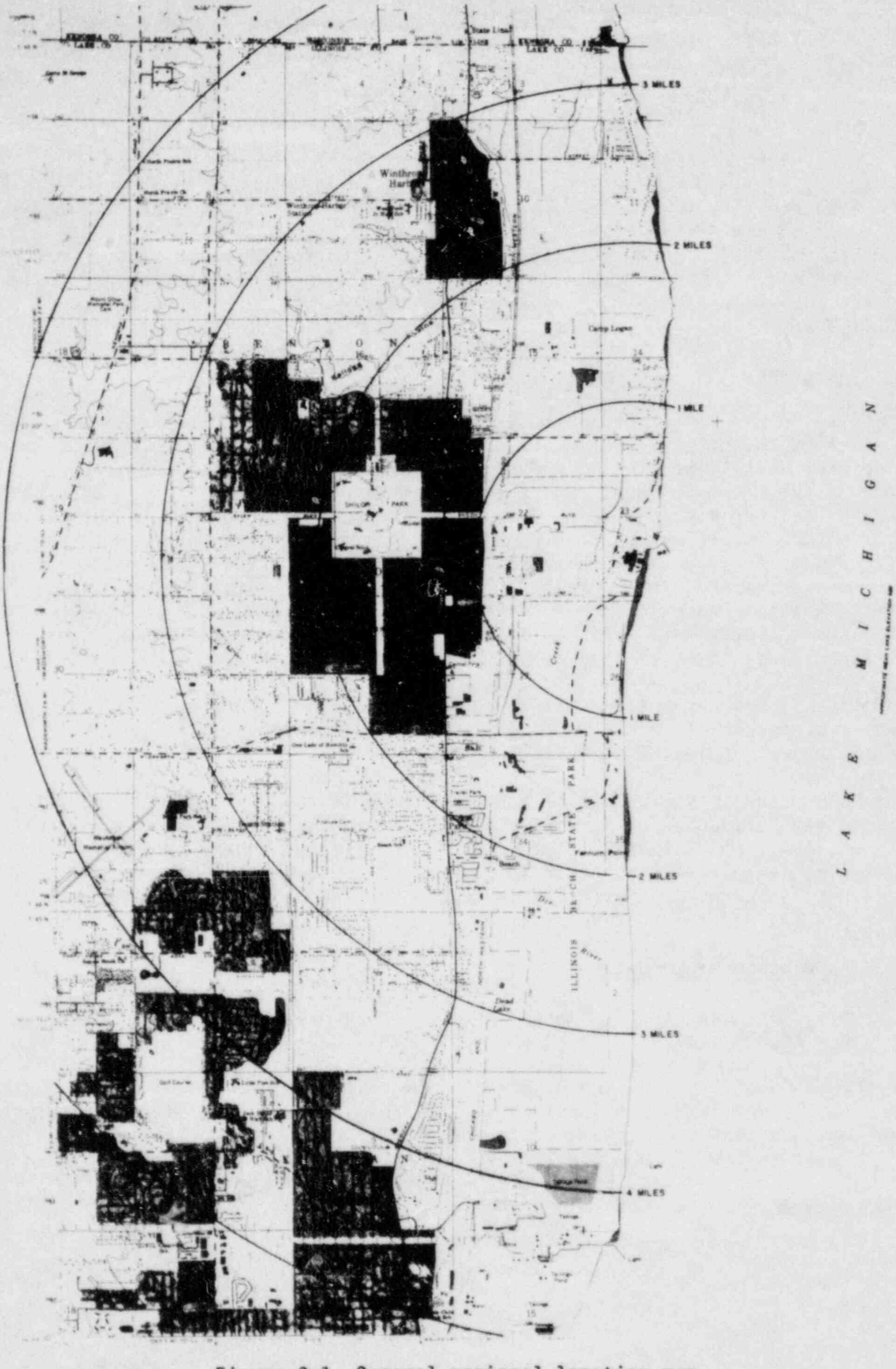

Figure 2.1 General regional location map

2.3 Nearby Industrial, Transportation, and Military Facilities

2.3.1 Industries

The Commonwealth Edison Zion Nuclear Power Station, where the WNTR is located, is a two-unit, 1,085 MWe boiling water reactor plant that has been licensed and operating since 1972. The Zion-Winthrop Harbor area is a small industrial region, with extensive farming to the west of the area. A major portion of this industry is located between the western boundary of the site and the Chicago and Northwestern Railroad tracks, approximately 0.4 mi due west of the WNTR location.

The centers of the communities of Zion and Winthrop Harbor are located about 1.2 and 2.5 mi, respectively, from the WNTR location. The areas within the Zion and Winthrop Harbor city limits are approximately 6.5 and 3.9 mi^2, respectively.

The industries in this area are considered to be light and should pose no threat to the safe operation of the reactor.

2.3.2 Railroads

The Chicago and Northwestern Railroad lies approximately 0.4 mi west of the WNTR site. Though the tracks are extensively used, the distance to the site is sufficient to preclude any risk to the safe operation of the plant.

2.3.3 Nearby Airports and Military Installations

The Chicago and Milwaukee commercial airports are located approximately 30 and 40 mi, respectively, from the site. The Great Lakes Naval Training Base (GLNTB) is located about 10 mi south of the WNTR site. The flight patterns of the commercial airports and the nature of the programs at GLNTB should pose no risk to the WNTR facility.

2.4 Meteorology

The climate of the region around the site is primarily continental, with characteristic cold winters and warm summers. There is no dry season; average annual precipitation, about 33 in., occurs with some uniformity throughout the year; average annual snowfall is about 40 in. and the mean annual temperature in the area is near 50°F.

Extreme winds are expected to exceed 70 mph only once every 50 years; the most extreme wind speed recorded was 87 mph in 1894. Tornadoes occur with relatively high frequency in Illinois, but are mostly found in the southern half of the state.

Northern Illinois is well-ventilated, with infrequent period of calms. Most frequent wind direction occurrences are southwest and northeast during the warm months of the year, and southwest and northwest during the cool months. The lake breeze effect is an important factor in wind direction during the summer months. The longest duration of uninterrupted winds blowing from one direction was 39 hours from the northwest.

2.5 Geology

A complex faulted zone near Des Plaines, Illinois, approximately 25 mi southwest of the site, is the closest known faulting to the site. Faulting exists in southern Wisconsin approximately 45 mi northwest of the site. However, there is no evidence of activity along any of these faults in recent geologic time, and there are no identifiable geologic structures that could be expected to localize earthquakes in the vicinity of the site.

2.5.1 Regional Geology

The site is located on the eastern flank of a broad, gently dipping anticline, the Kankakee Arch, which separates two major downwarps of the earth's crust, the Michigan basin to the northeast and the Illinois basin to the south. The LaSalle Anticline to the southwest of the site forms the northern side of the Illinois basin and is believed to be pre-Pennsylvanian.

Bedrock in the region consists of Paleozoic sedimentary rocks, which rest on the Precambrian basement rock. The thickness of the Paleozoic sedimentary rocks in northeastern Illinois is approximately 4,000 ft. The bedrock dips gently toward the east at a rate of about 10 ft per mile.

The bedrock surface in the northeastern Illinois region is covered by a thick mantle of glacial drift. The advancing glaciers scoured major stream valleys and formed the large depressions now occupied by the Great Lakes. The glacial drift deposited by the glaciers consisted of till, outwash, and lacustrine deposits. Recent deposits in the region consist of unconsolidated sand, silt, and peat.

Bedrock at the site is Niagara Dolomite of Silurian age, which is moderately fractured and may contain solution cavities. These cavities are usually filled with clays and sand. There is a slight possibility that in the unlikely event of a collapse of a solution cavity in the plant area, plant operation could be affected.

2.5.2 Local Geology

The site is located on a narrow strip of lake deposits that borders the Lake Michigan shoreline. Crossing the WNTR and adjacent Zion site is a series of low, parallel, beach ridges composed primarily of sand and separated by marshy depressions. Organic materials have accumulated in the depressions.

The site is blanketed by granular lake deposits, which range in thickness from 24 to 33 ft and consist of fine and fine-to-medium sand containing variable amounts of coarse sand and gravel and occasional pockets of peat and organic material. The granular lake deposits are underlain by Pleistocene glacial till, glacial outwash, and glacial lacustrine deposits, which extend to depths ranging from approximately 102 to 116 ft below the existing ground surface. The glacial tills and glacial lacustrine deposits are firm to hard and are relatively impermeable. A detailed description of the subsurface conditions may be found in the Zion PSAR.

2.6 Hydrology

2.6.1 Surface Water

The Lake County Public Water District has located a water intake about 1 mi north of the Zion site and about 3,000 ft out in the lake. This action negated the use of wells, except as standby water sources.

2.6.2 Lake Hydrology

The normal water level of Lake Michigan is approximately 580 ft above mean sea level (MSL). The maximum recorded water level is 583.2 ft above MSL, which occurred in 1886.

A detailed description of the currents, tides, waves, and littoral drift appears in the Zion PSAR. A maximum elevation of wave run-up and wind tide was estimated to be 6.7 ft above the normal water level (at an occurrence frequency of once in 500 years). A maximum seiche level of 5 ft above lake was considered for the Zion site. Because the WNTR facility is located 3,250 ft from the shoreline land at an elevation 6.8 ft, flooding could not occur.

2.6.3 Ground Water

Ordinarily there will be no potable uses of ground water in the Benton or Waukegan Townships. There are wells in the communities of Zion and Winthrop Harbor (Benton Township) that are maintained on a standby basis to meet emergencies. Of these wells, the one with the highest yield is 1,025 ft deep as a result of a 700 ft drop in the artesian pressure of the deep aquifers since 1864. These wells are located near the southern edge of Shiloh Park, about 1.5 mi west of the Zion plant location. Considering this location and the topographical divide that causes surface water to drain toward the east, any effects on these ground water supplies is very unlikely. Ground water is near the surface over much of the site area. The beach ridges project slightly above the water table, and most of the intervening depressions are marshy and are at or slightly below the water table. A very slight ground water gradient trends to the east and south. A stagnant condition now generally prevails between the beach ridges.

2.7 Seismology

Northeastern Illinois is a region characterized by infrequent occurrences of low-to-moderate intensty earthquakes. The Seismic Zone Map of the United States prepared by the U.S. Department of Defense, dated 1966, also indicates that the area is a zone of minor seismic probability. The site itself is free of known seismic disturbance.

Since the beginning of the 19th century, two earthquakes with epicentral intensities of VII, Modified Mercalli Intensity (MMI) Scale of 1931 (Wood), and with epicenters within a distance of 60 mi of the site are known to have occurred. The first of these earthquakes, near Fort Dearborn, Illinois, occurred in 1808 at an epicentral distance of approximately 35 mi from the site. The second occurred in 1909 south of the Illinois-Wisconsin border near

Beloit, Wisconsin, at an epicentral distance approximately 60 mi from the site. Including the earthquakes described above, three earthquakes are known to have occurred within a distance of 50 mi with epicentral intensities ranging from MMI III to VII, and nine earthquakes have been recorded within 100 mi with epicentral intensities ranging from MMI II to VII. In addition to these, a few very great but distant earthquakes may have been felt at the site but with very low intensity.

2.8 Conclusion

The staff has evaluated the WNTR site for man-made as well as natural hazards and concludes that there are no significant hazards associated with this site that would pose an undue risk to its safe operation.

3 DESIGN OF STRUCTURES, SYSTEMS, AND COMPONENTS

3.1 Description of the Reactor Building

The building housing the WNTR is constructed of concrete and steel supports and is located within a 90- by 100-ft restricted area. The reactor room is a 27-ft-long by 27-ft-wide by 27-ft-high cube solidly constructed of 8-in.-thick concrete block walls with a 5-in.-thick concrete floor. The concrete pit and reactor dump tank are centered in the room. Two doors provide access to the reactor room: an emergency/equipment entrance exterior door, 3 by 9 5/6 ft, that only unlocks from the inside and a similar interior door that provides the main access to and from the reactor room and that is controlled from the console room during reactor operation. Entrance into the reactor room is controlled by a licensed reactor operator. The facility layout diagram is shown in Figure 1.1.

3.2 Wind Damage

As described in Section 2.4 wind velocity is only rarely expected to exceed 70 mph. The construction of the building is able to withstand these wind velocities.

3.3 Water Damage

Surface and geohydrology are described in detail in Section 2.6. Because of site elevation, it is highly unlikely that floods resulting from either precipitation or Lake Michigan wave conditions will affect the site.

3.4 Seismic-Induced Reactor Damage

As indicated in Section 2.7, the site is located in a low seismic-intensity zone. Therefore, it is highly unlikely that any seismic activity could pose a risk to the safe operation of the reactor.

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 1972 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 are maintained at an acceptable level of performance.

3.6 Conclusions

From the above description and evaluation of the reactor facility, the staff concludes that the WNTR 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. In addition, the staff concludes that the performance of the control-rod-drive system will continue to be adequate.

4 REACTOR

The Westinghouse Nuclear Training Reactor (WNTR) is an open-pool type light-water moderated and shielded, graphite-reflected, highly enriched uranium-aluminum low-power reactor. The highly enriched uranium-aluminum fuel is contained in aluminum-clad fuel tubes. A standard fuel element is an array of three concentric fuel tubes.

Heat generated from fission is removed from the core by natural convection of the water coolant.

The reactor facility, which is used largely by Westinghouse customer personnel, has served as a nuclear training facility in the areas of fundamental reactor physics and reactor operations. The design and performance characteristics of the WNTR are summarized in Table 4.1. Although the reactor is licensed to operate at levels not to exceed 10 kW, the applicant indicated that normal operation is generally around 0.1 kW. For example, total thermal power developed from 1972-1983 is only 400 kW-hours.

4.1 Reactor Core

The reactor core includes 19 standard fuel elements and 5 aluminum clad cadmium control rods with fuel element followers in a hexagonal configuration. The core is below ground and located in the lower portion of an 8-ft-diameter, 19-ft-deep aluminum tank asymmetrically located within a 12-ft diameter by 24-ft deep dump tank (see Figure 4.1).

The reactor core consists of a lattice containing 144 positioning holes in the lower grid plate for fuel elements, control rods, associated shroud tubes and experimental equipment. The 24 uranium-aluminum fuel elements/ control rods, which are held in a hexagonal array by upper and lower grid plates connected by core position guide tubes (shrouds) and several tie rods, are held in position by gravity. There also are several experimental positions. The normal core region forms a smaller hexagon. The core contains ~4.8 kg of ^{235}U. Water coolant occupies ~75% of the core volume. The radial reflector is composed of 20 graphite reflector rods loaded in a hexagonal configuration surrounding the fuel elements. Top and bottom axial reflection is provided by the aluminum upper and lower grid plates and by the water in which the core is immersed. The current core configuration is shown in Figure 4.2.

4.1.1 Fuel Elements

The WNTR fuel elements consist of three concentric tubes of aluminum-clad uranium-aluminum alloy fuel that are held in this configuration by web brackets. The fuel-bearing sections are 36 in. long and contain ~200 g of ~13 wt % highly enriched (93.5%) uranium. The outside diameter of the fuel element is 2 1/2 in., and the complete length of the fuel elements is 47 5/16 in. The individual fuel element tubes are 1/8 in. thick with the center of the fuel element serving as a position for inserts, such as an aluminum thimble that would be supported by the upper web bracket of the fuel element. Although not

Table 4.1 Current WNTR design and performance characteristics

General Feature	Characteristics
Reactor	
Type	Pool, highly enriched, water moderated, graphite reflected, tank type
Licensed rated power level	10 kWt
Normal operating power	100 W or less
Core shape and size	Active section approximates a 36 in. wide hexagon, 36 in. high, 6061 - aluminum
Reactor tank	8 ft diameter, 19 ft high, 3/8 in. thick aluminum
Current core configuration	19 fuel elements, 5 control rods with fuel followers
Current fuel loading	4.8 kg ^{235}U
Neutron source	PuBe (α, n) 2 Ci, location variable
Moderator/coolant	light water (resistivity >200,000 ohm-cm)
Reflector	20 graphite reflector rods, 2 ft light water loaded in the core
Reactor control rods	1 safety rod (cadmium with aluminum cladding) 4 shim rods, rectangular configuration (cadmium with aluminum cladding) Rack-and-pinion control rod drive Normal withdrawal speed Safety 3.75 in./min Shim 5.60 in./min Fast cutback speed Safety 26.3 in./min Shim 39.0 in./min Maximum allowed rod drop time <1.2 s
Minimum critical fuel loading	21 standard fuel elements, 5 control fuel elements, and 20 graphite reflector rods
Excess reactivity	4.4% $\Delta k/k$ (5.50$)
Shutdown margin, normal loading	17.7% $\Delta k/k$ (22.10$), clean core
Clean-cold critical mass	4.2 kg ^{235}U [with 20 (type 683) graphite-reflector rods]
Effective delayed neutron fraction (β)	0.0080% $\Delta k/k$ (1.00$)
Reactivity Worths	
Safety rod	10,060 pcm 10.06 $\Delta k/k$ (12.58$)
Shim rod (average)	2620 pcm 2.62% $\Delta k/k$ (3.27$)
Temperature coefficient at 80°F	-1.7×10^{-3}% $\Delta k/k/°F$ (-0.0021$/°F)

Table 4.1 (continued)

General Feature	Characteristics
Average void coefficient	(0.323% $\Delta k/k$/% void fraction) (0.41\$/% void)
Average thermal flux at 10 kW (graphite reflected)	4.08×10^{10} n/cm^2/s
Peak thermal flux at 10 kW	10.9×10^{10} n/cm^2/s
Prompt neutron lifetime	5×10^{-5} s
<u>Fuel Elements and Control Rod Fuel Element Followers</u>	
Fuel elements	24 (19 fuel elements and 5 cadmium control rods with fuel element followers)
Total weight	14 lbs each
Enrichment	93.5% U^{235}
Maximum U^{235} per fuel element	200 g
Fuel material	Alloy (13 w/o U-Al metal)
Control rod fuel with element follower	44 in.-long three-tube fuel element linked to control rod by stainless-steel coaxial rod, with top shaft coupling and bottom piston device

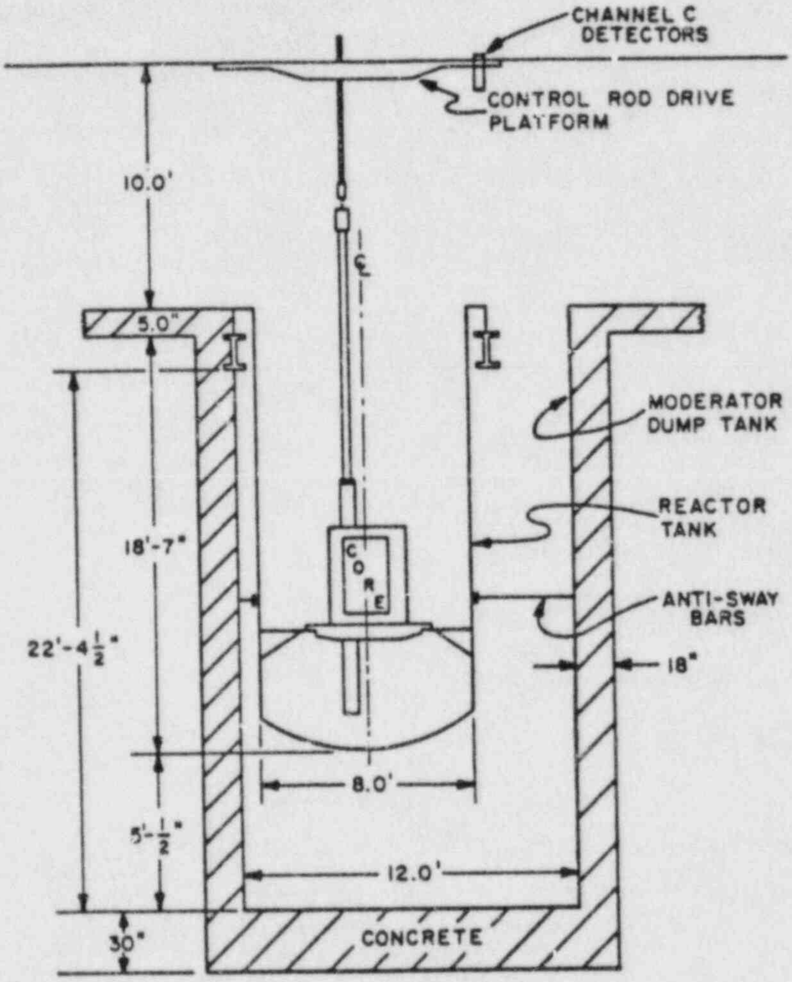

Figure 4.1 Reactor assembly

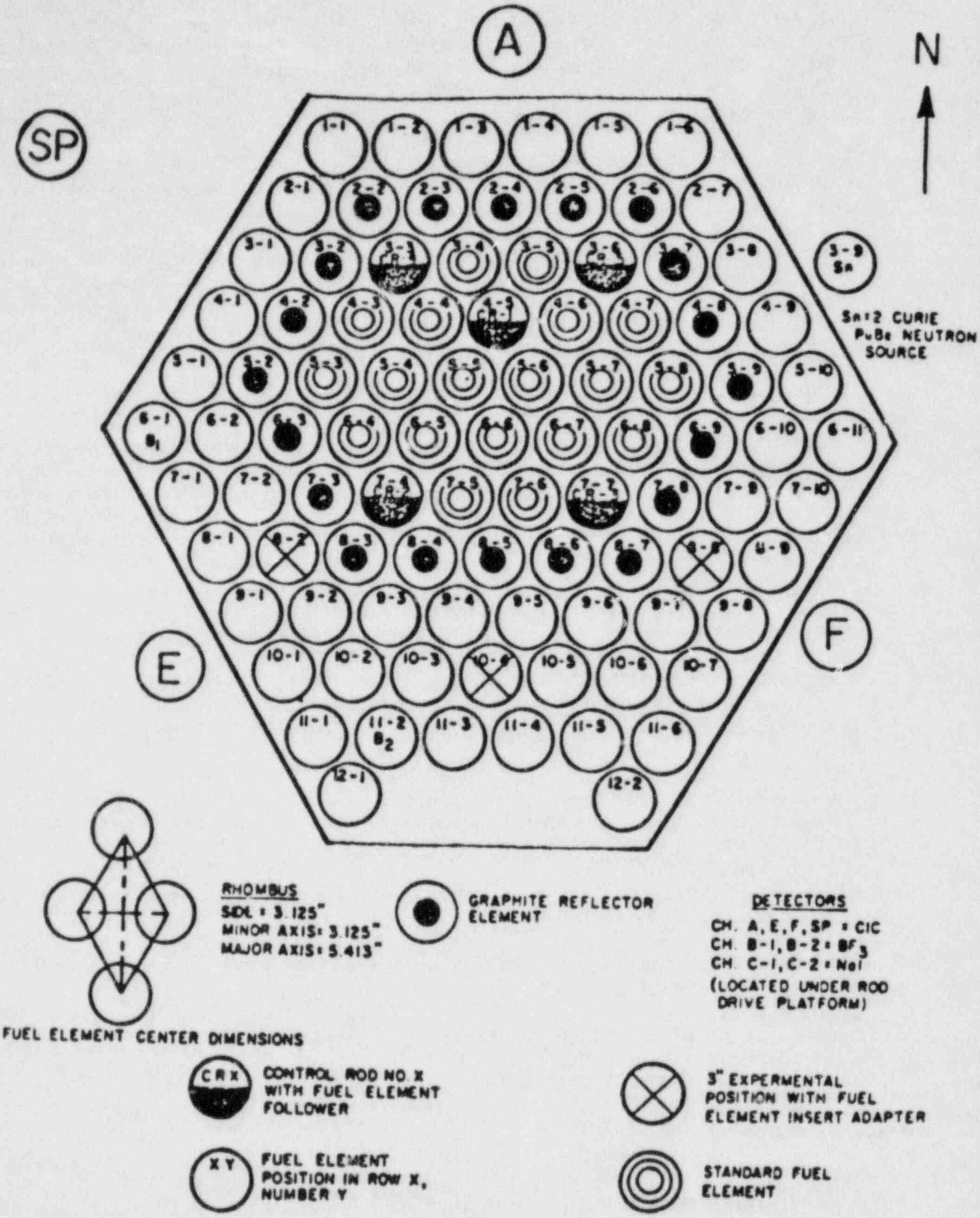

Figure 4.2 Current core diagram for the Westinghouse nuclear training reactor

loading for any element is 200 g of ^{235}U. Each fuel element includes a top bracket for grappling by a fuel element handling tool. Figure 4.3 shows a detailed schematic diagram of the standard fuel element.

4.1.2 Graphite Reflector Rods

Twenty-one graphite reflector rods may be used to fill grid positions not occupied by the fuel elements, control rods, or other core components or assemblies. The 21 graphite reflector rods (type 683 graphite) are 2.625 in. in diameter and 48 in. long, and have a 0.5-in.-diameter hole bored axially along the length of the rod where a 0.5 in. aluminum support rod is located. A ball-joint handling adapter is mounted on the top of each aluminum support rod where the handling tool positively latches for loading and unloading, similar to the fuel element handling tool. Figure 4.4 shows a typical graphite reflector rod.

4.1.3 Control Rods

Reactor control is provided by five control rods located inside the fuel element configuration of the core (see Figure 4.2). The inner rod is the safety rod and the outer rods are the shim rods. All rods drop on a scram indication. Control rods are 36 in. long and 2 1/2 in. in diameter with 1/8-in.-thick walls of cadmium clad with 1/10-in. aluminum. Connected to the control rods for movement and safety are a magnet armature, connecting linkage rods, a stop cup, a 44 in. fuel element follower section, and a shock absorber, all of which are linked together by a stainless-steel coaxial rod. The 44-in. fuel element followers, similar to standard fuel elements, become part of the active core as the poison section of the control rods is withdrawn. Aluminum tube shrouds that extend above and below the core grid plates guide the control rod travel and also contain holes in the bottom that provide a shock-absorbing dampening capability. A typical control rod in a guide tube is shown in Figure 4.5.

The control rods are driven electrically by a rack-and-pinion drive mechanism located above the core. An electromagnet attaches the drive mechanism to the control rods. Deenergizing the magnet produces a reactor trip and allows the control rods to fall freely into the core by gravity. A scram indication causes all five control rods to drop. The control rod locations in the current core are shown in Figure 4.2.

The maximum reactivity worth of the safety and shim rods for the current core, measured individually, are as follows:

Safety rod	1	10.060% Δk/k
Shim rod	2	2.720% Δk/k
Shim rod	3	2.775% Δk/k
Shim rod	4	2.525% Δk/k
Shim rod	5	2.450% Δk/k
		20.530% Δk/k

However, when measured as a bank, the worth is slightly greater and is measured at 22.1% Δk/k. The difference in the measurements is due principally to the shadowing effects that occur during individual rod worth measurements.

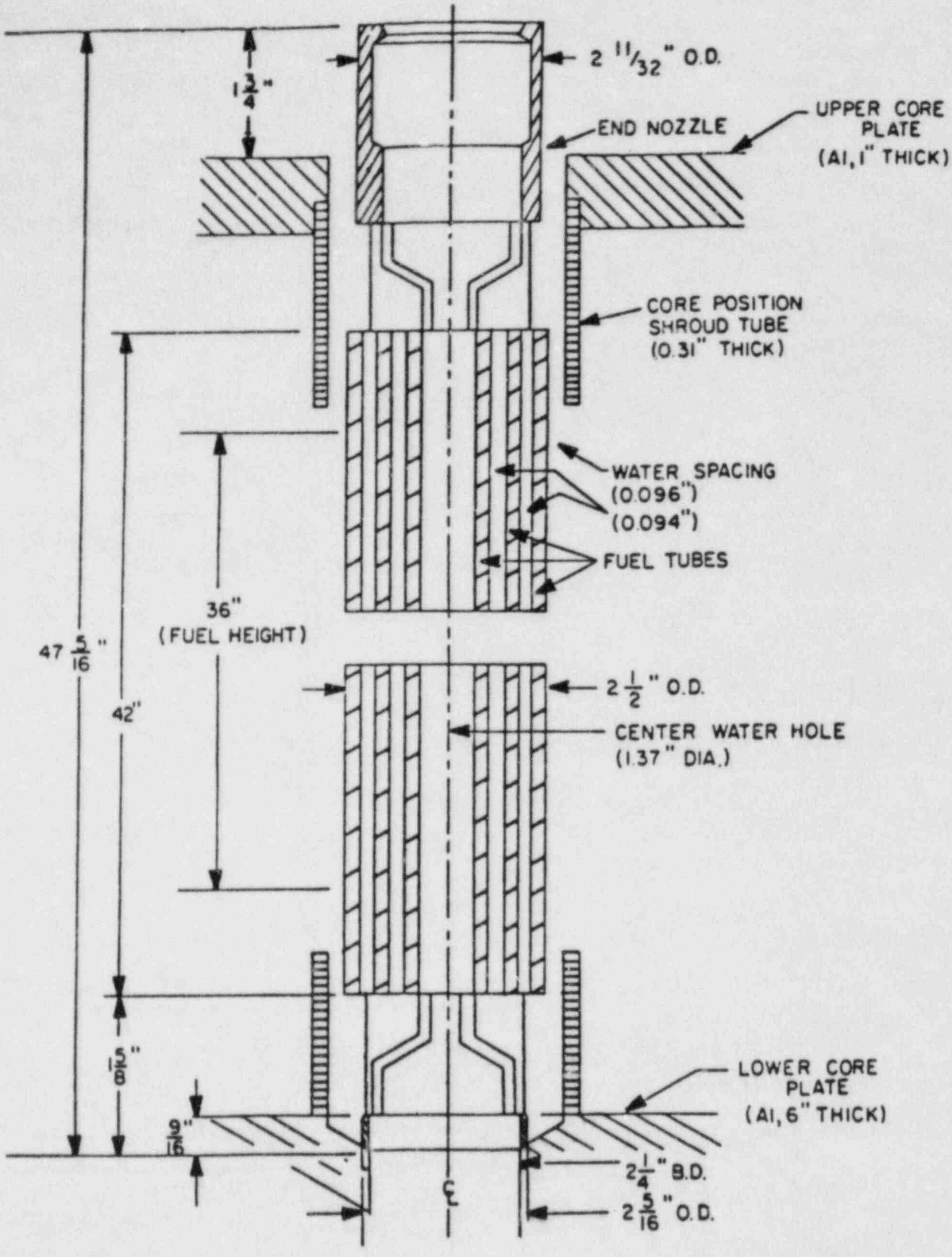

Figure 4.3 Standard fuel element

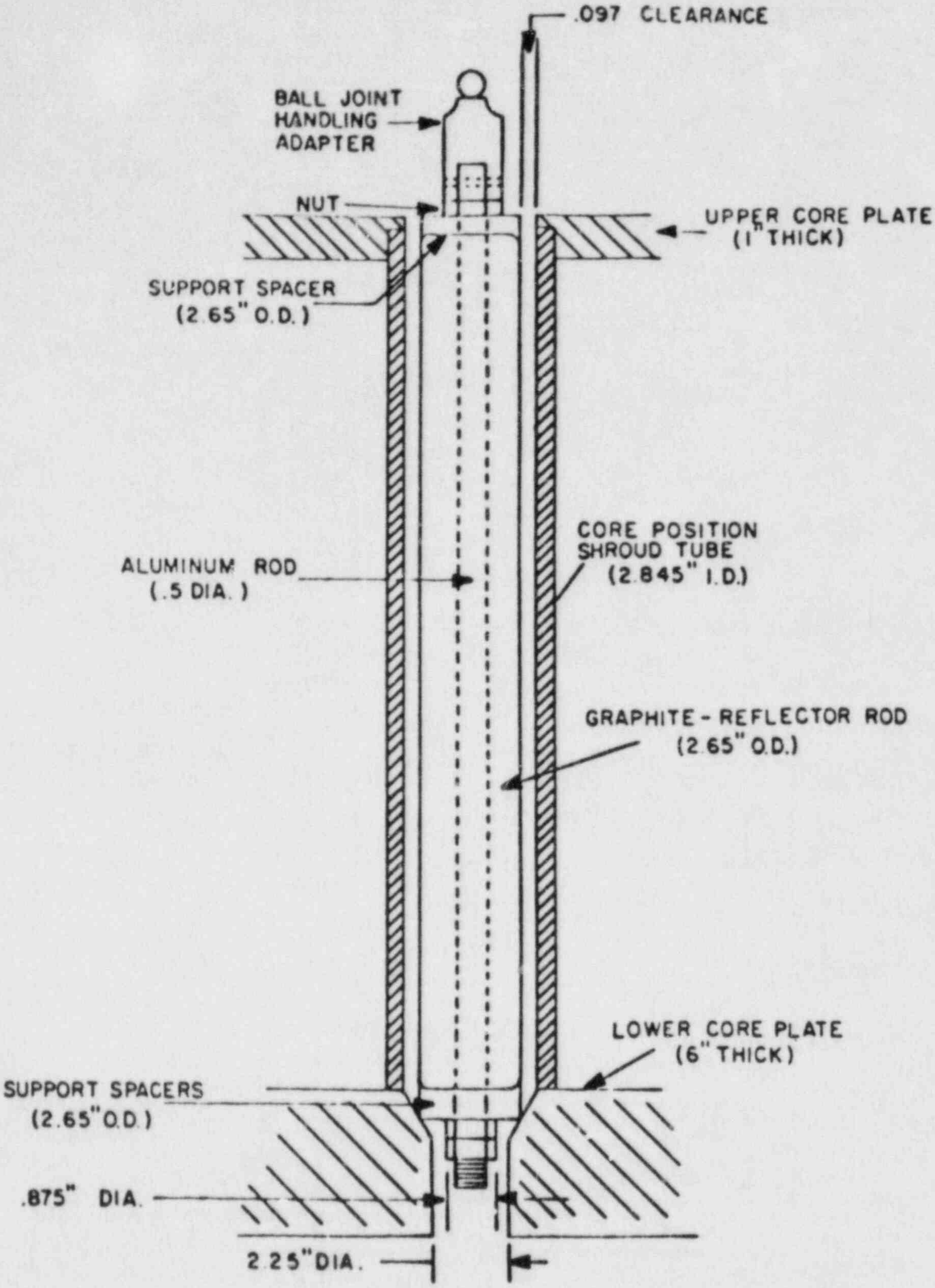

Figure 4.4 Graphite reflector rod

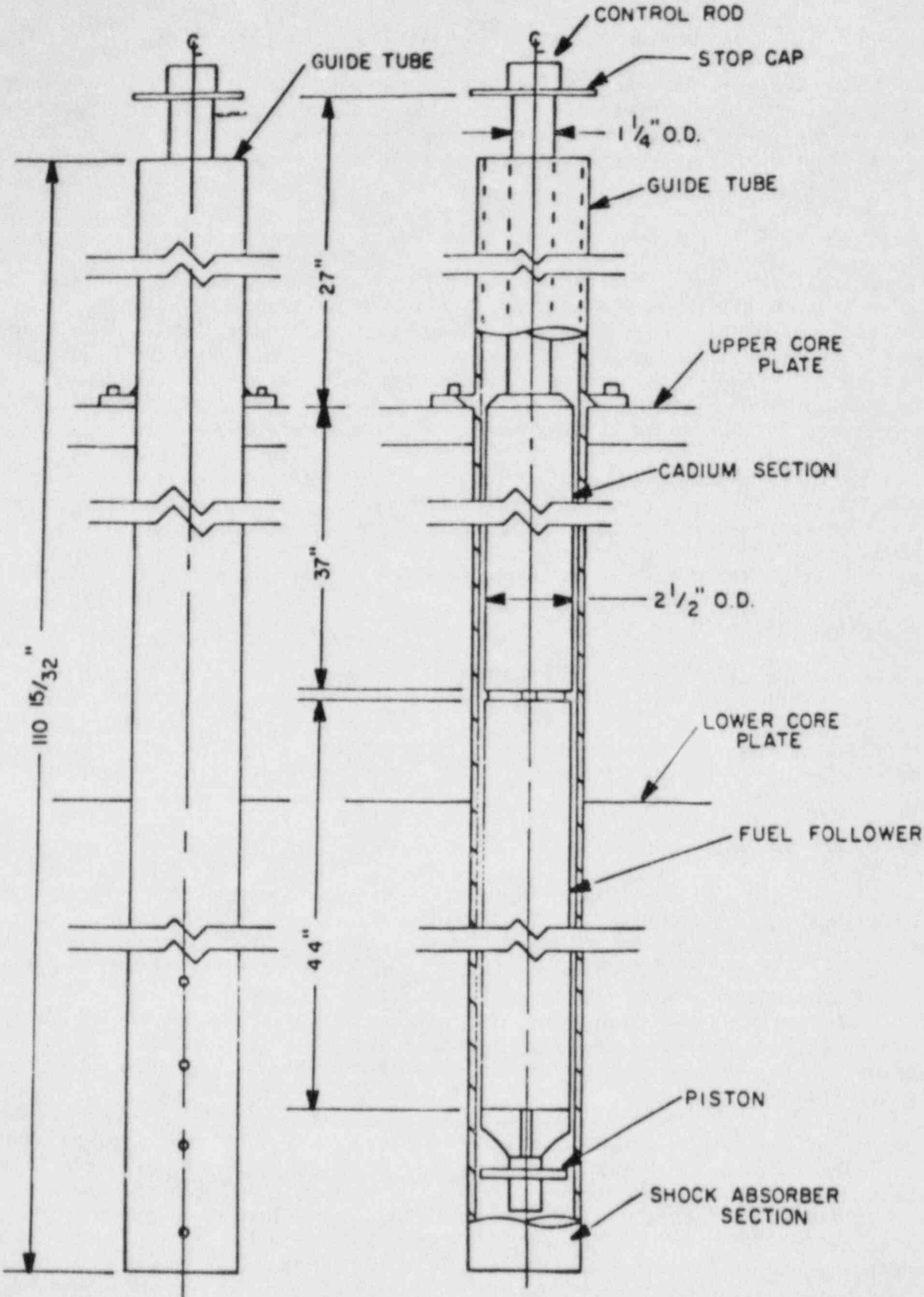

Figure 4.5 Control rod in guide tube (partially removed)

4.1.3.1 Functional Design of Reactivity Control System

Each rod drive system is controlled from the reactor control console and has independent cables and circuits, which minimizes problems of multiple malfunctions of the drive units. When a reactor scram signal is received, all five rods will insert by gravity into the core, rapidly decreasing the reactivity of the reactor.

4.1.3.1.1 Control Rod Drives

The control rod drives are mounted on a platform bridge assembly that spans the core. The drive assemblies consist of a normal-speed drive motor, a fast "cutback" speed drive motor, an electromagnetic friction clutch, a speed-reducing gear train, a position indication transmitter, and rack-and-pinion gears (see Figure 4.6). The control rods are coupled to the drive system through an electromagnetic carriage and can be operated singly or together. If power to the magnets is interrupted, the rods fall into the core by gravity.

Electromechanical devices and circuits that limit vertical movement, rate of movement, and scrams are typical of those used in research reactors. For normal operations, shim rod movement speeds are 5.6 in./min and the safety rod speed is 3.75 in./min. This prevents the maximum allowable positive reactivity addition rate limits from being exceeded. A fast speed "cutback" motor provides insertions of the shim rods of 39 in./min (shim) and 26.3 in./min (safety). Rod indication is to within 0.02 in.

Relays on each of the control rods must be energized for rod withdrawal for positive reactivity insertions. If power to the relays is interrupted, the rods automatically drop by gravity. A manual means of deenergizing the electromagnets and inserting the control also is provided in the reactor console and the reactor room. A simplified schematic diagram of the control rod drive unit is shown in Figure 4.7.

4.1.3.1.2 Scram-Logic Circuitry and Interlocks

The scram-logic circuitry and interlocks ensure that several reactor core and operational conditions are satisfied before allowing reactor operations to start or to be maintained. There are two basic modes of initiating a reactor scram: (1) interruption of the rod control drive power or (2) the opening of the moderator-shield water dump valve that drains the reactor tank water to the dump tank. An automatic reactor scram can be caused by any one of four nuclear instrumentation signals. All scram signals will deenergize the electromagnets on the control rods and cause the rods to insert, thereby causing the reactor to shut down.

The Technical Specifications for the WNTR require that one source range channel trip, two startup and power channel trips, one gamma level channel trip, and one period channel trip are operating during reactor operation to ensure the reactor is rapidly shut down if the settings are reached or exceeded. The Technical Specifications also require a manual trip to be located in the console and reactor room. The minimum required nuclear instrumentation channels are shown in Figure 4.8.

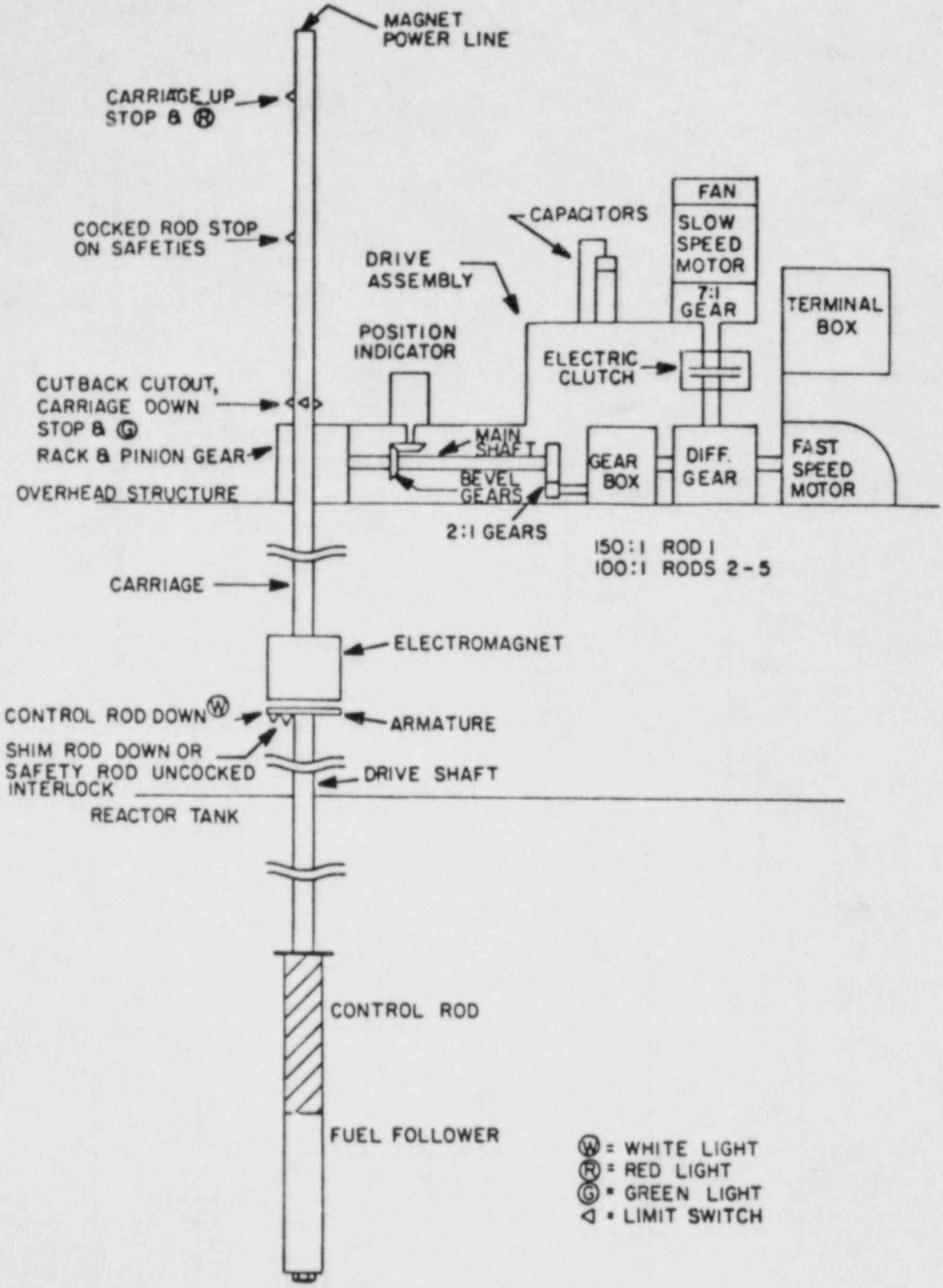

Figure 4.6 WNTR control rod drive mechanism

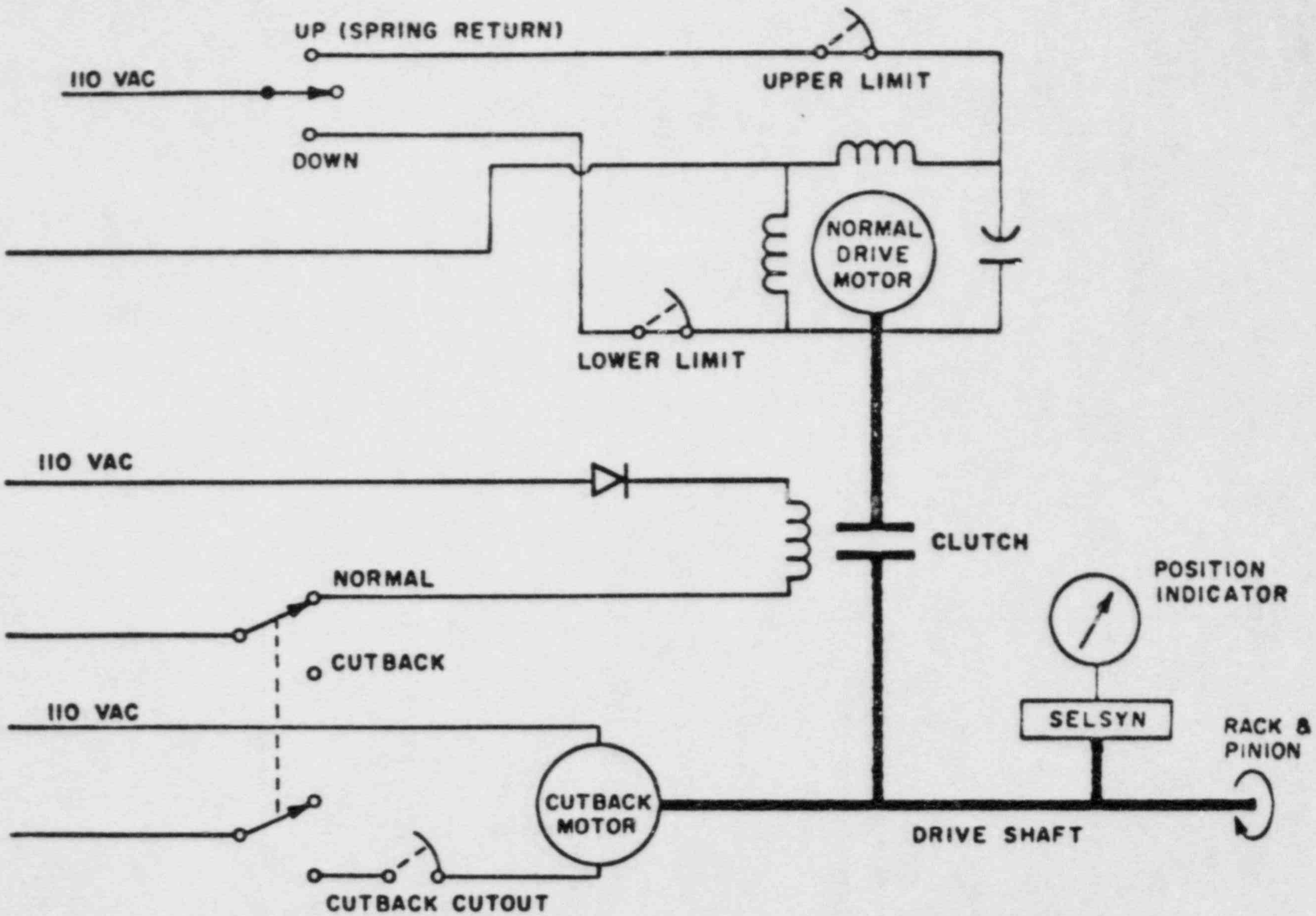

Figure 4.7 WNTR control rod drive simplified schematic

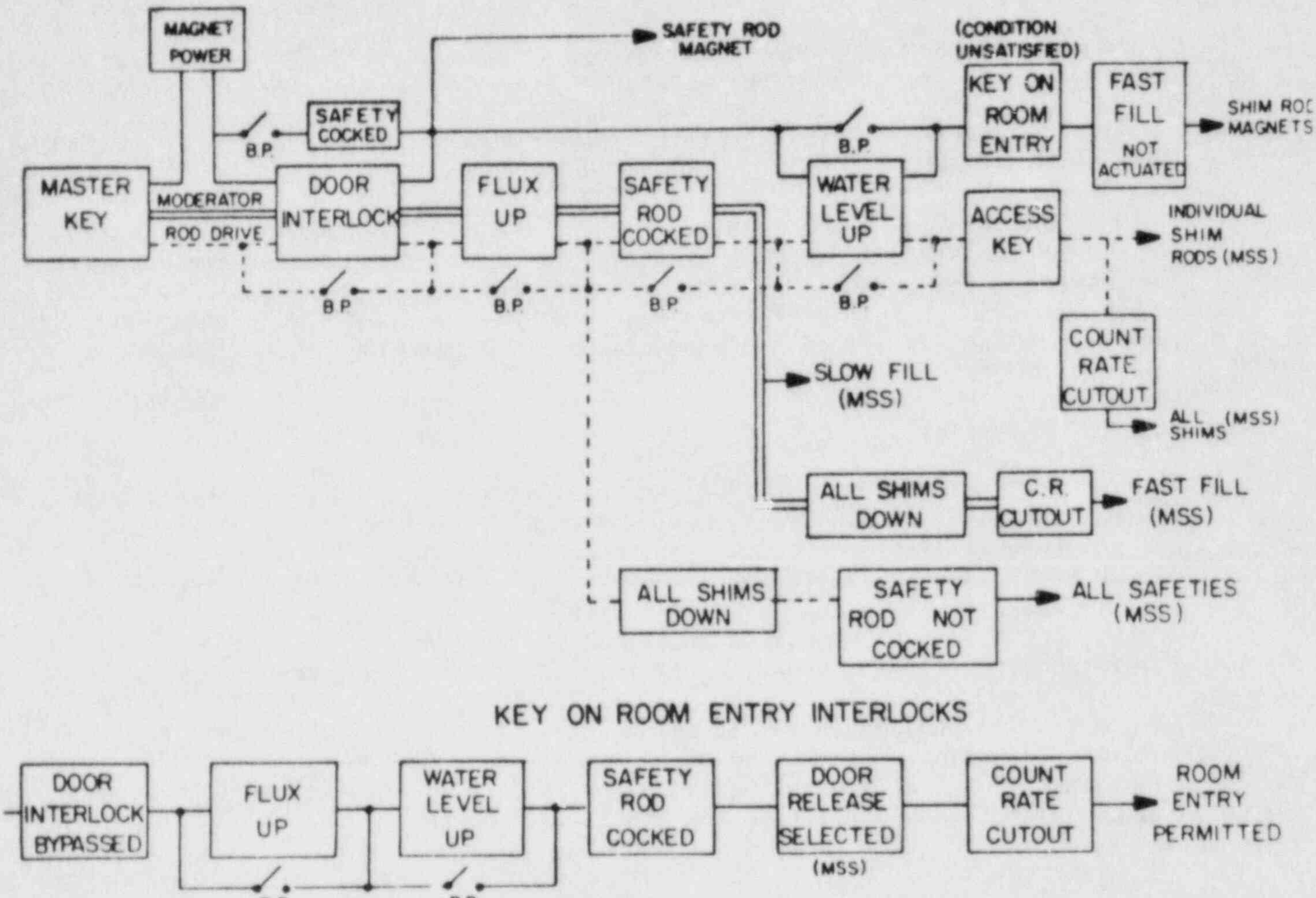

Figure 4.8 Minimum nuclear instrumentation channels

The second mode for initiating a reactor shutdown is by manually emptying the moderator water. This auxiliary reactor trip, located in the control and the reactor rooms, allows for the introduction of negative reactivity by reducing the reactor moderator water level within 1 min of the actuation of the trip. This auxiliary trip also is automatically initiated at the console when electric power to the console and/or air pressure to the dump valve is lost.

Several safety interlocks are incorporated into the control rod circuitry to prevent inadvertent positive reactivity insertions, thus ensuring that proper and safe reactor conditions exist and that the correct sequence of operations is performed.

Control rod withdrawal is prevented unless an adequate signal is provided to allow the proper startup of the reactor. This interlock system is arranged to permit positive reactivity to be added by only one rod at a time. The operator must manipulate and maintain positive pressure on a specific switch to institute a reactivity change.

The minimum interlocks and required actions are shown schematically in Figure 4.8 and are discussed in Section 7.4. Interlock bypasses are available for preoperational checks and safety checks; however, no bypass allows the remote addition of reactivity when personnel are in the assembly area, and each bypass and its associated annunciator are displayed on the control room console.

4.1.3.1.3 Conclusions

The WNTR is equipped with a safety and control system that incorporates multiple control and safety rods, interlocks, and multiple and redundant sensors that can initiate a reactor scram and shut down the reactor. There are enough redundant systems available and the control rods have an adequate amount of negative reactivity so that even if the control rod with the most reactivity worth fails to insert when a scram signal is received, the remaining rods still supply sufficient negative reactivity to safely shut down the reactor.

In addition to the electromechanical safety controls for both normal and abnormal operation, there is an auxiliary system shutdown scram that dumps the moderator, plus the inherent negative moderator void coefficient to provide additional margin to shut down the reactor.

The staff concludes that the reactivity control systems of the WNTR are designed and function so that the safe operation and shutdown of the reactor under all credible conditions is ensured.

4.1.4 Moderator

Demineralized light water is used to moderate and shield the reactor. Water level normally is maintained at a minimum of 5 ft above the core. In addition, a 10-in. and a 1-in. drain line, both located below the core, may be used to remove water from the reactor tank.

4.1.5 Neutron Source

A 2-Ci PuBe (α, n) neutron source is included in the core assembly to provide a significant neutron population before startup operations. The source can be positioned into the core manually by a capsule that is attached to a chain or remotely by an electrically driven special assembly that can position the source vertically in and out of the reactor. Interlocks ensure manual and remote placement of the source into the reactor before reactor startup.

4.2 Reactor Tank

The reactor tank is a 0.375-in.-thick 6061-T6 aluminum cylinder 19 ft deep and 8 ft in diameter. The open-ended tank is suspended inside the dump tank by four horizontal I-beams such that the outer wall is 6 in. from the west side of the dump tank. Other horizontal support rods attached ~5 ft from the bottom of the reactor tank prevent horizontal motion of the reactor tank within the dump tank.

4.3 Reactor Support Structure

The core structure is supported by a 1-in.-thick, 26-in.-wide aluminum ring that is supported by eight 1/2-in.-thick aluminum gussets welded 4 ft from the bottom of the reactor tank.

4.4 Reactor Instrumentation

Several instrumentation channels are used in the nuclear training reactor to monitor neutron flux and gamma levels. The minimum instrumentation requirements for reactor operation consist of two source range neutron-sensitive channels, one with an effective reactor trip for reactor operation <0.99 k_{eff}. Two startup and operating-level neutron detectors, for flux level monitoring, one flux rate-of-change detector with reactor trip, two flux level reactor trips, and one gamma level detector with reactor trip capabilities are required for reactor operation when k_{eff} is >0.99. The neutron-sensitive detectors are located in watertight containers in the core periphery, and the gamma detector is located above the upper water shield over the core.

Two BF-3 ion chambers are used as the startup channels; one compensated ion chamber is used for measuring the reactor power from source level to full power and two CIC chambers measure reactor power from source level x 100 to greater than or equal to full power. A gamma-sensitive ion chamber provides reactor power indication from 100 W to greater than or equal to full power. In addition, it has safety functions including a reactor scram if there is a loss of reactor shielding water.

The neutron flux is monitored from the source range to >12 kW, and there are interlocks that limit the reactivity insertion rates and the power. In addition, the interlock system permits positive reactivity to be added by only one means at any particular time, and a positive pressure must be applied and maintained to effect any reactivity additions.

4.5 Biological Shield

The biological shield of the WNTR consists of deionized water in the reactor tank, the reactor tank itself, and the reinforced concrete surrounding the dump tank. The dump tank structure provides 30 in. of concrete on the bottom and 18 in. of concrete on the sides. Vertical shielding is provided by 5 ft of water above the top of the reactor core and 4 ft of water below the bottom of the reactor core.

4.6 Dynamic Design and Evaluation

In response to the changes in the observed and measured parameters such as reactor power, neutron flux, and reactor period, operation and/or adjustment of the safety and shim rods is done only manually. The fixed reflector rods and fuel elements provide a constant neutron flux distribution.

The reactor core is designed to have a negative void coefficient and negative moderator temperature coefficients. The maximum voiding on a loss of coolant removes the principal neutron moderator and shuts down the reactor. In addition, interlocks prevent inadvertent reactivity additions and reactor scrams provide shutdown when safety settings are exceeded.

4.6.1 Excess Reactivity and Shutdown Margin

The maximum excess reactivity that can be loaded into the reactor core, including that associated with experiments or possible experiment failure, is limited by Technical Specifications such that the reactor can be made subcritical by at least 1.00$ with the highest worth rod stuck fully out of the core. The normal fuel loading has a 4.4% $\Delta k/k$ (5.50$) of excess reactivity. The Technical Specifications limit with the highest worth rod stuck out of the core would be 6.84% $\Delta k/k$ (8.55$).

The reactivity worth of any movable experiment is limited to 0.20% $\Delta k/k$ (0.25$). The reactivity worth of any individual unsecured experiment is limited so that a failure of any experiment or its associated equipment will not result in a positive reactivity addition of more than 0.64% $\Delta k/k$ (0.80$). In addition, the reactivity worth of all unsecured experiments is limited so that a common mode failure of all such experiments and their associated equipment will not result in a positive reactivity insertion of more than 0.64% $\Delta k/k$ (0.80$).

As stated above, the excess reactivity of the current WNTR core is 4.4% $\Delta k/k$ (5.50$). The shutdown margin with all control rods fully inserted is 17.7% $\Delta k/k$ (22.13$). Their sum yields a total control rod worth of 22.1% $\Delta k/k$ (27.63$). The highest worth rod is worth 10.06% $\Delta k/k$ (12.58$). Thus, under these conditions, the shutdown margin with the highest worth rod fully withdrawn is 7.64% $\Delta k/k$ (9.56$). Therefore, the current configuration meets the limits on excess reactivity and shutdown requirements of the Technical Specifications.

4.6.2 Normal Operating Conditions

The Technical Specifications limit the operation of the WNTR to a maximum power level of 10 kWt. Operational records, however, indicate that the WNTR normally operates at a power level of 0.1 kW, which is well below the maximum licensed safety limit.

4.6.3 Experiments

The Technical Specifications provide limitations on the reactivity worths and reactivity insertion rates for the experiments, as well as the material composition of the experiments.

The Technical Specifications limit the reactivity worth of any unsecured experiment and accident or sum of all unsecured experiments in the core to 0.64% $\Delta k/k$ (0.80$). An accident involving insertion of this amount of reactivity would result in a reactor period of 1 s, causing a period trip at the 3.5 s setting, scramming the reactor, and thus preventing an excessive power level from being reached. The value of 0.80$ is more conservative than the value used by Westinghouse in the accident analysis.

Experimental samples and devices that can be inserted or removed by remote means are limited to 0.20% $\Delta k/k$ (0.25$). As this is well below the accidental step reactivity insertion value discussed above, it ensures that the reactivity changes occurring during the insertion and withdrawal of the experiments can be controlled.

In addition, experiments are limited in that they cannot be composed of or contain any explosive material or other material that can produce a violent chemical reaction and/or airborne radioactivity. These restrictions minimize the possibility of any explosions or fires in the vicinity of the reactor and minimize personnel and public radiation exposures.

4.6.4 Conclusions

The staff has reviewed the proposed limitations on the worth of the unsecured experiments and the insertion/withdrawal worths associated with the experiments and concludes that they are conservative and provide reasonable assurance that failures of any experiment(s) or device(s) resulting in positive reactivity insertions would not result in damage to the reactor components or fuel. On the basis of this information, the staff concludes that the limitations of the Technical Specifications will provide assurance that 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 the proposed minimum shutdown margin of $\geq$0.80% $\Delta k/k$ (Δ1.00$) with the highest worth control rod fully withdrawn is sufficient to ensure that the reactor can be shut down adequately under all likely conditions.

4.7 Operational Procedures

The WNTR has implemented a program that incorporates reviews, audits, and written procedures for all safety-related activities. A Reactor Safeguards Committee (RSC) reviews the WNTR activities and confers with Westinghouse management on all matters pertaining to the safe operation of the facility. Specific areas of responsibility for the RSC include reviews of new experiments, tests, and facility modifications not covered in the Safety Analysis Report, Technical Specifications, normal operating/emergency procedures and/or their associated changes, facility compliance with regulations, procedures, and license provisions, and performance of facility apparatus and equipment.

The RSC also performs quarterly and semiannual audits of the facility and its associated equipment. Operating procedures, approved by the RSC, have been established for reactor startup operation, shutdown operation, radiation safety practices, fuel handling, preventive or corrective maintenance, emergency procedures, radioactive material and waste handling procedures, security operations, training, and experimental procedures.

The WNTR management has procedures for a preventive maintenance program and preoperational checklist to ensure that all the safety-related components meet their respective functional Technical Specifications before the reactor is operated at power.

The WNTR is operated by trained NRC-licensed personnel in accordance with the above-mentioned procedures.

4.8 Conclusion

The staff has performed a review of the WNTR facility design, control and safety instrumentation, operating practices, Technical Specifications, and other pertinent documentation associated with the reactor. These features are similar to those of many other pool-type research reactors, and on the basis of the review of this reactor and experience with similar pool-type reactors with highly enriched fuel, the staff concludes that the WNTR is capable of continued safe operation.

5 REACTOR COOLANT AND ASSOCIATED SYSTEMS

5.1 Primary Cooling System

The heat energy produced in the core is dissipated to the reactor tank water by natural convection. The reactor coolant-moderator-shield, which is demineralized water with a resistivity greater than 200,000 ohm-cm and a pH between 4.5 and 8.0, is normally maintained at a level of 5 ft above the core during operation. At maximum power level operation of 10 kWt, the temperature increase of the reactor coolant is less than 5 °F. Thus, there is no need for a secondary cooling system for the rejection of heat. The reactor coolant level is controlled by the water makeup system. Whenever the reactor coolant is dumped, the reactor shuts down and the core is cooled by natural air convection.

5.2 Water Makeup System

The water makeup system (Figure 5.1) allows remote filling and emptying (dumping) of the reactor tank. The filling system is controlled by the operator, who must satisfy the sequential interlock system before adding water to the reactor tank. The water fill system includes one sump pump that takes suction from the reactor dump tank; two electrically actuated, air-operated valves; appropriate manual valves; and piping. The fill rate is controlled by two paralleled valves in the fill main. Slow fill (35 gal/min) is initiated by opening one of the valves that has a flow rate reducing orifice installed in its line. Fast fill (120 gal/min) is initiated by opening both valves. When the normal operating water level (5 ft above the core) is reached, the float switch in the reactor tank automatically closes both valves.

The drain system consists of a 10-in. valve on the dump line that is capable of emptying the reactor tank (to 28 in.) on demand from the operator. A 1-in. valve is installed in the bottom drain line of the reactor tank to allow complete emptying of the reactor tank. The reactor tank water is emptied into the reactor dump tank.

5.3 Primary Water Purification System

The water purification and makeup system (Figure 5.2) provides demineralized water for the reactor system and maintains the water specific resistivity above 200,000 ohm-cm and its pH between 4.5 and 8.0. Water coolant in the reactor dump tank is recirculated through the demineralizer (one or two ion exchange columns, as necessary) to maintain the above water specifications. For makeup, water from the Zion City water system is run through the demineralizer and then to the reactor dump tank. All valves and controls in this system are operated manually.

5.4 Conclusion

The staff concludes that the reactor coolant and associated systems are adequate for continued safe reactor operations.

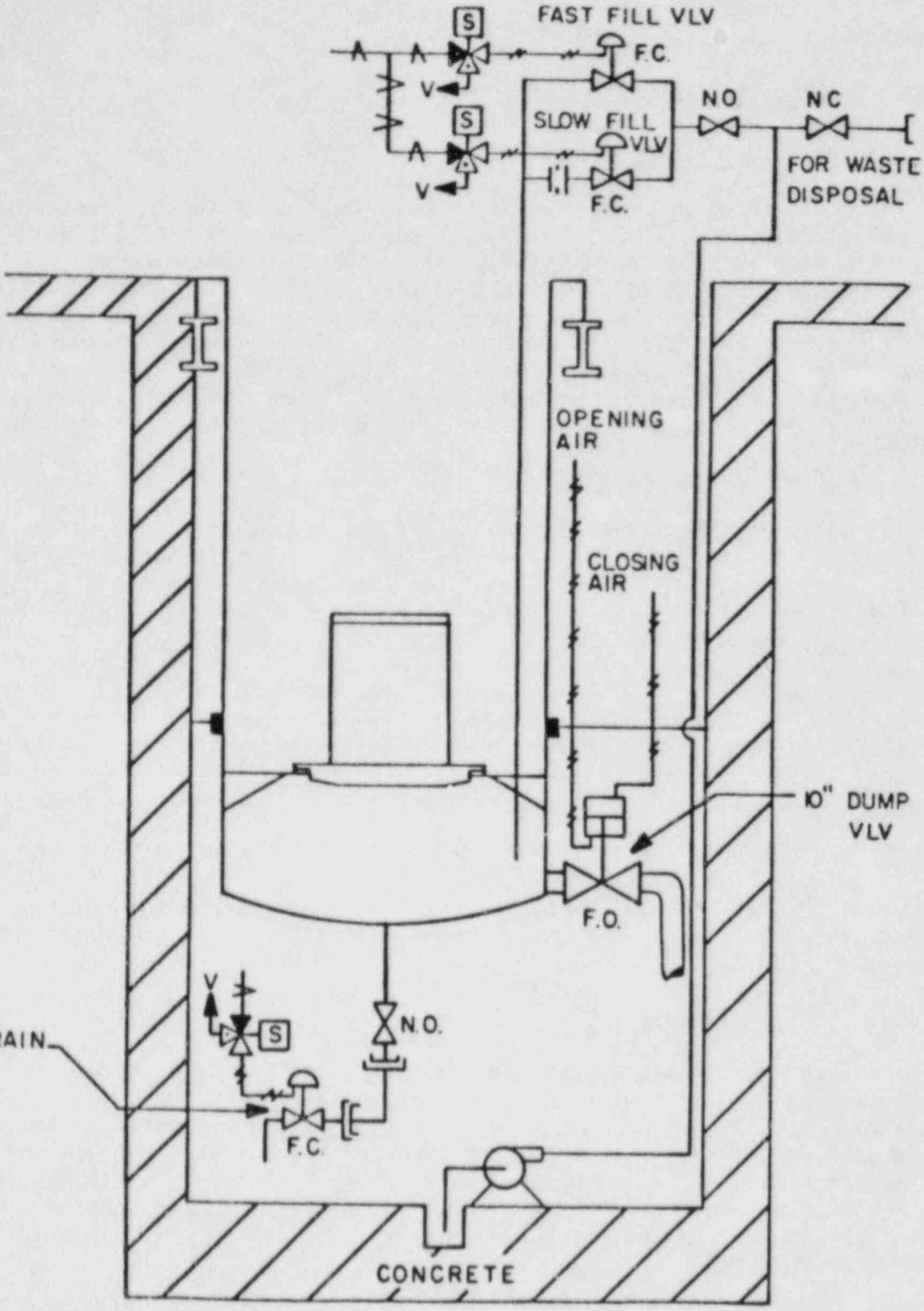

Figure. 5.1 Moderator shield water system

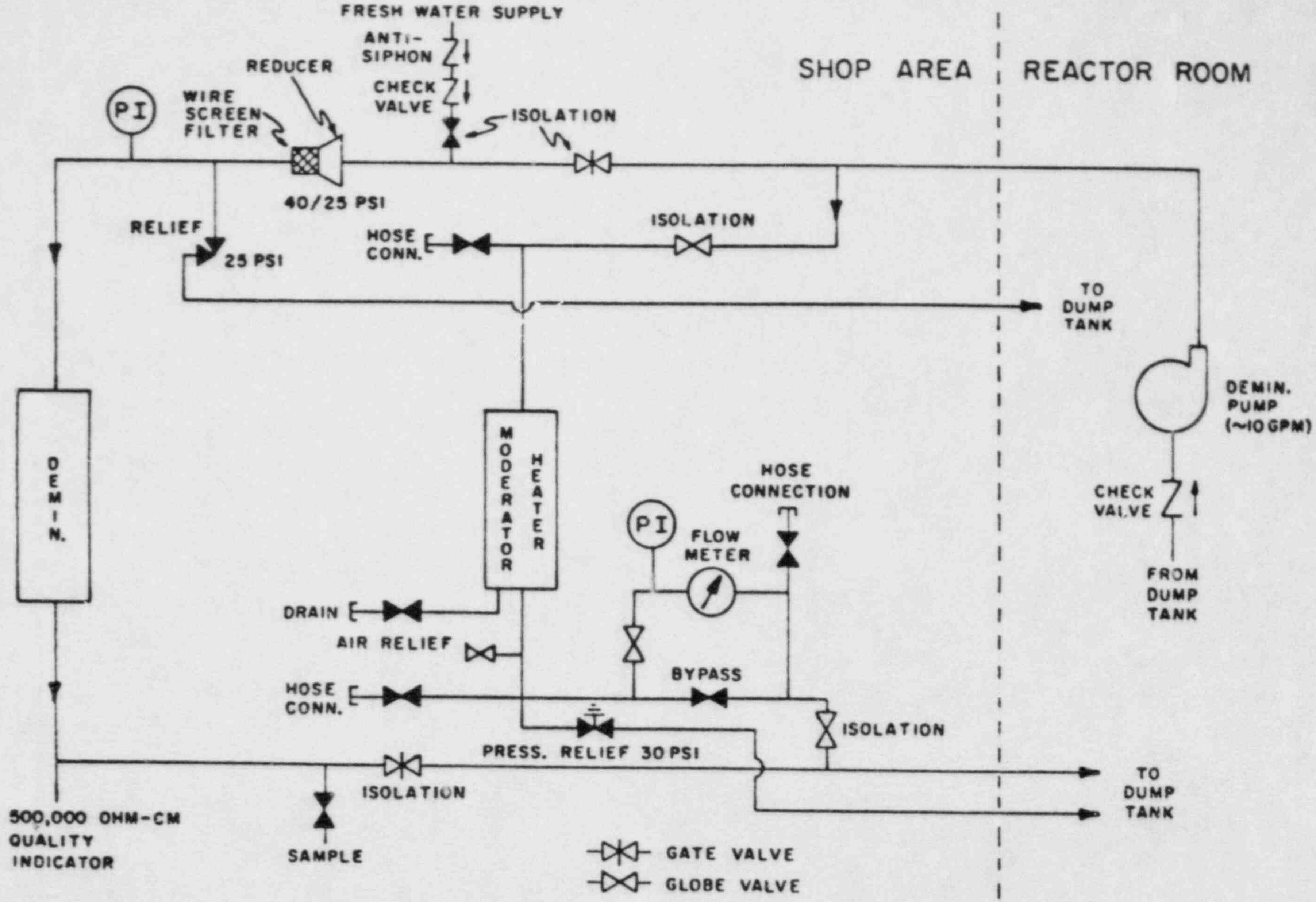

Figure 5.2 Water purification system

6 ENGINEERED SAFETY FEATURES

Engineered safety features are those features or systems that mitigate the consequences of an accident. The two features that can be considered as engineered safety features at the WNTR are the dump valve of the water handling system and the reactor room exhaust system.

6.1 Dump Valve

The dump valve, located in the dump line of the water handling system, is an electrically actuated, air-operated, 10-in. valve. Although normally manually actuated, the valve will fail open on loss of electrical power or loss of air pressure to the valve operator. Once actuated, the moderator water from the core drains into the reactor dump tank within 1 min. Without the water moderator, negative reactivity is inserted and the reactor shuts down.

6.2 Reactor Room Exhaust System

The reactor room ventilation system consists of a louver and an exhaust fan in the roof of the reactor room. Supply air to the reactor room is a once-through system and is directly discharged outside the building via the exhaust stack. The exhaust fan and the air supply to the reactor room can be secured from the equipment room. Because of this, the consequences of a potential radiological release from the reactor room can be controlled.

6.3 Conclusions

The staff concludes that the dump valve system, as an auxiliary scram system, independent of the control rods of the reactivity control system, is capable of shutting down the reactor. Because the fission product inventory is small the staff concludes that the securing of the ventilation system will maintain accidental fission product releases within the reactor room so that no significant amount of radioactivity will be released to the environment.

7 CONTROL AND INSTRUMENTATION

The WNTR control and instrumentation systems are designed to safely control and shut down the fission process. The instrumentation system is composed of nuclear and process instrumentation and is interlocked with the control system.

7.1 <u>Control System</u>

The control system is composed of both nuclear and process control equipment in which safety-related components are designed for redundant operation if a single failure or malfunction of components, necessary for the safe operation or a shutdown of the reactor, occurs.

7.1.1 Nuclear Control Systems

The safety and shim rod drive mechanism and control systems are described in detail in Section 4.1.3.

Automatic scrams, which release the rods by the interruption of electrical power to the magnetic carriages holding the control rods in place, are initiated by

(1) a reactor power level exceeding the safety setting as indicated by the log-N, linear power level, or linear-γ level channels

(2) a reactor period less than a preset value

(3) loss of electrical power

A manual auxiliary reactor trip is operator-initiated by opening the dump valve and expelling the moderator-shield water into the dump tank, thus shutting down the reactor by its inherent moderator void coefficient mechanism. The dump valve also opens when the electrical power to the console and/or air pressure to the valve is lost. In addition, the reactor operator can initiate manual scrams by (1) operating the manual scram button that interrupts the electrical power to the reactor console or (2) removing the reactor console master key that interrupts the permissive bus that allows the rods to be withdrawn.

The minimum safety channels for reactor operations prescribed by the Technical Specifications are listed in Table 7.1.

7.1.2 Supplementary Control Systems

The supplementary control systems are provided to control various systems in the WNTR that are not related directly to the safety systems. These control systems provide circuitry and mechanisms that energize and maintain control on the ventilation/heating systems; the air conditioning system; the compressed air system, which supplies a source of 50-psig compressed air to maintain the

Table 7.1 Minimum reactor safety channels

Safety Channel (Range)	Functions
Log Count Rate (source range)	Prevents withdrawal of control rods
Log-N (source x 100 to >full power range)	Provides period scram and high neutron level scram for control of ramp reactivity insertion rates
Linear-N (source to >full power range)	Provides high neutron level scram and a reactivity addition disconnect to prevent reactor overpower conditions from occurring
Linear-γ (100 W to full power)	High γ level scrams to provide for public and operations personnel protection from high radiation exposures resulting from an overpower condition

moderator-shield water dump valve in a closed position; the water purification system, which uses conductivity probes to measure the purity of the water; and the devices that monitor the coolant process parameters such as temperature, conductivity, water level, and radiation level area monitors.

7.2 Instrumentation System

The instrumentation system is composed of nuclear and process control instrumentation circuits. The annunciations and/or indications are supplied to the reactor console and reactor control room by the electrical system. The reactor's instrumentation that is located at and controlled from the reactor console consists of

(1) all rod control switches
(2) rod position indicators for four shim rods and one safety rod
(3) annunciator lights indicating the position and direction of each associated rod
(4) recorders and annunciator panels in the reactor control room that provide indication for

    (a) linear and log-N power levels
    (b) reactor period
    (c) log count rate
    (d) linear-γ power levels
    (e) radiation alarms and indications
    (f) emergency alarms
    (g) coolant water parameters and indications
    (h) additional lights for indication of power on, startup source position, and the source of any scram signals

Radiation levels are measured inside the reactor room, near the entrance to the facility, and in the console room. An audio and visual alarm is actuated if the gamma level reaches a predetermined value in the monitor inside the reactor room. In addition, there is a manual emergency alarm that can be actuated from the reactor console or at the main entrance of the WNTR facility. Coolant water parameters such as temperature, water level, and conductivity are monitored, with indications in the control room. Startup source position indication and power-on/master-key-on indication also is available in the control room, along with indication of the source of any scrams.

7.3 Nuclear Instrumentation

The nuclear instrumentation provides the operator with the appropriate information for the proper manipulation of the control rods.

(1) Log-Count-Rate Channel--This is the major source range channel and receives its signal from a BF_3 detector. The log-count-rate channel is used primarily to monitor the neutron power during startup.

(2) Linear-N Power Channel--This channel receives a signal from a compensated ion chamber. It monitors the reactor power level from startup to greater than full power and provides a signal for the automatic scram circuitry and interlock functions. It also provides a signal for the automatic reactor power level control.

(3) Log-N Power Channel--This channel receives a signal from a compensated ion chamber. It monitors the reactor power from 100 times the initial source range value to greater than full power. It transmits a signal to the period amplifier that provides for reactor flux rate protection and also gives indication of the reactor period. In addition, it provides a signal to the reactor trip system for high power protection and also provides a signal for the reactor power level indications.

(4) Linear-γ Channel--This channel receives its signal from a scintillation detector that monitors the reactor power level (γ) and also provides a redundant scram signal for abnormally high reactor power levels. This is the major safety channel and has a range of 100 W to greater than full power.

The neutron detectors are located in watertight containers in the peripheral region of the core. The gamma detector is located above the upper water shield over the core. All detectors are movable (only channel A normally is adjusted) to allow for adjustment or calibration with the thermal power derived from gold foil activation. The nuclear instrumentation and control set points are shown in Table 7.2.

7.4 Reactor Interlocks and Annunciators

Interlock signals that permit rod withdrawal for reactor startup are provided by the following:

(1) Low log-count rate in the source range neutron channel interlock--If the channel recorder is not operable or if it is not indicating greater than

Table 7.2 Nuclear instrumentation and control set points

Type Channel	Detector	Range	Automatic Control	Scram Set Points Min	Scram Set Points Max
Log Count Rate (LCR) and Scaler	Proportional	Source Level	Reactivity Addition	2 cps	--
			$0.1/s Mode Cutout	2 cps	Source Level x 100
Log-N	Ion Chamber	LCR Source Level x 100 to > Full Power	Period Scram	3 s	--
			Level Scram	--	12 kW
Linear-N	Ion Chamber	Source Level to > Full Power (Manual Decading Required)	Level Scram	--	98% of Full Scale
			Reactivity Addition Disconnect	5% of Full Scale	--
Linear-γ	Scintillation or Ion Chamber	100 W to > Full Power	Level Scram	--	12 kW

2 counts/s, rod withdrawal is not permitted. This ensures that a high reactivity insertion rate cannot be permitted unless the startup channel is indicating in an observable level. There is also a high level cutout associated with the log-count-rate channels at source range x 100 value to prevent high startup rates.

(2) Reactor room door--If the reactor room door is not closed, power from the shim and safety rods (if they are not cocked) is removed, and control rod withdrawal is not permitted. This ensures that no personnel are inside the reactor room when a startup is attempted.

(3) Flux-up on the linear-neutron channel--The linear-N channel that is used from source to full power ranges must be operable and indicating >5% of full scale, or no reactivity is inserted. This ensures that a sufficient neutron population exists and is being monitored. In addition, a startup source position indication is located in the control room.

(4) Safety rod cocked--The safety rod must be withdrawn approximately 17 in. (3.5 turns) or power to the rod drive and moderator fill switches is lost. This ensures that adequate, excess negative reactivity is available before startup.

(5) Water level--A float switch 5 ft above the core must be actuated or rod withdrawal power (except to cock the safety rod) is lost. This ensures that enough moderator is available so that any water level change caused by any startup accidents will not add any significant positive reactivity (moderator void coefficient is negative).

(6) Shim rod lower limit switches--Shim rods must be inserted to their lower limits or rod withdrawal is not permitted and the safety rod cannot be cocked. This is to ensure that reactivity is added by only one means at a time.

Four interlock bypasses also are permitted to allow preoperational and safety checkouts. Each bypass is displayed on the control console. All bypasses (on interlocks 2, 3, 4, and 5 above) prevent the remote addition of positive reactivity when personnel are in the area. Figure 7.1 shows the preset integrated interlock system and its associated functions.

A control console and annunciator panel supply the operator with information on important variables relevant to the operation of the reactor. Following annunciation of an event, the condition must be verified and corrected.

7.5 Conclusions

The control and instrumentation systems at the WNTR are well designed and properly maintained. For the important ranges of neutron power level, there are redundant circuits provided by overlapping the log-count rates and linear-neutron-level channels. The specific instruments are in excess of those required for operation. The control system is designed so that the reactor is shut down automatically if electric power is lost or interrupted.

On the basis of the review of the control and instrumentation systems, the staff concludes that these systems are adequate, ensure safe operation of the reactor, and satisfy all the existing regulations and requirements. Thus, the reactor can be operated safely within the context of the proposed Technical Specifications and license conditions.

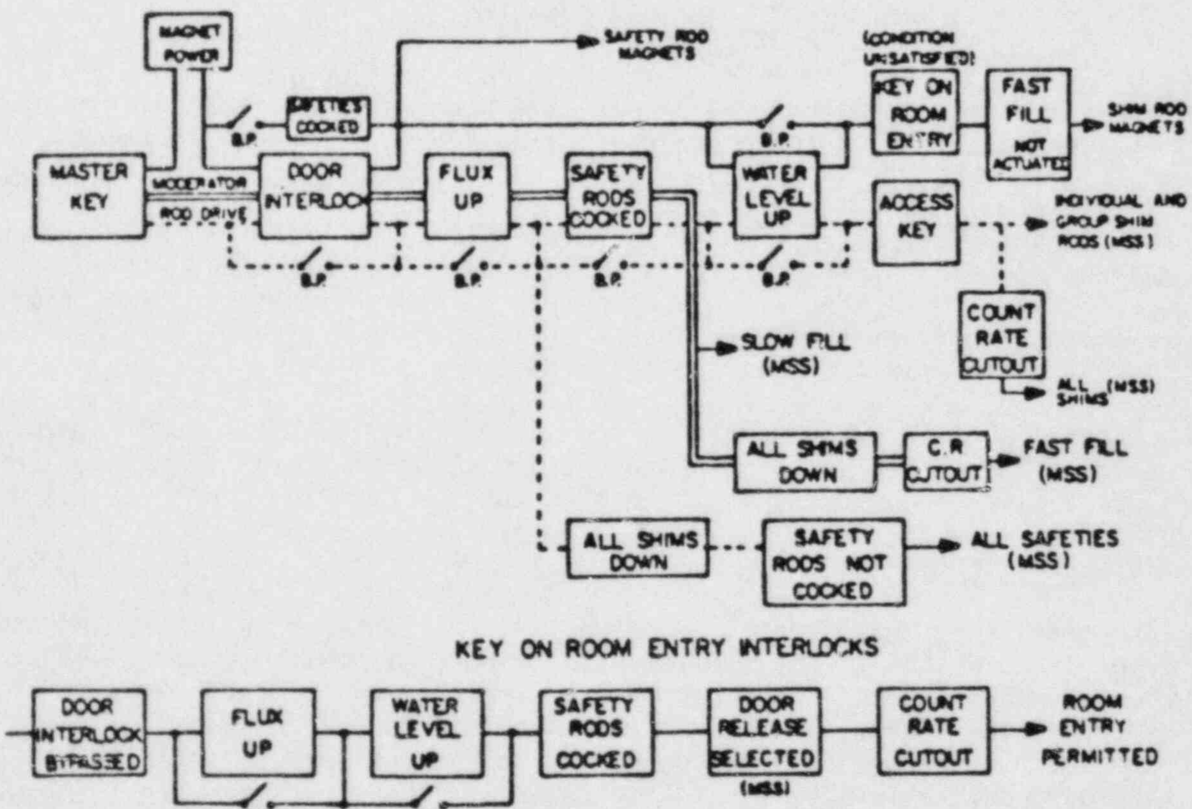

Figure 7.1 Interlock system

8 ELECTRIC POWER

8.1 Electrical Power System

The electrical power for building lighting and reactor instrumentation is standard commercial single phase, 60 Hz, 120/208 V, which is furnished through a transformer and several control panels located throughout the building. Because the reactor control rods will scram in the case of an electrical power interruption and the decay heat generated in the core following a scram does not require emergency cooling facilities, no emergency power is needed or supplied. Battery-powered emergency lighting is available to facilitate personnel movement during a power outage.

8.2 Conclusion

The staff concludes that no emergency power is necessary and that the design of the electrical power system and the inherent safety of the reactor design are adequate to ensure the safe operation of the WNTR.

9 AUXILIARY SYSTEMS

9.1 Water Purification System

The high quality of the demineralized water is maintained principally to ensure the integrity of the fuel elements and other heat transfer surfaces in the reactor. The WNTR facility water purification system is described in Section 5.3.

9.2 Fuel Storage

The main fuel storage area for the WNTR is located against the west wall of the reactor room. A high-density concrete barrier surrounds the storage area for radiation shielding. A gamma-sensitive area monitor and its associated alarm and annunciator are located near the main fuel storage area to provide for criticality protection.

Six additional fuel storage tubes are mounted on the reactor tank wall. The tops of these racks will normally be shielded by approximately 4.5 ft of water.

Control rods, with their fuel followers, when removed from the core, are stored in a rack in the reactor room that is shielded by a high-density concrete wall.

9.3 Radiation Monitoring Equipment

There are three area radiation monitors available in the facility. Two of these can be used for personnel contamination monitoring and are located near the main entrance to the facility and in the control room. The third monitor, located in the reactor room, alarms if the gamma radiation level increases to the preset value and also serves as a criticality monitor for the special nuclear material storage area.

A facility emergency alarm that is actuated manually from the console or the main entrance door of the WNTR facility alerts personnel if there is any potential danger from a reactor system malfunction.

In addition, there are several portable radiation monitors located throughout the facility that are capable of measuring expected radiation types (β, γ, α, and n) and levels.

The minimum number and types of portable radiation monitors that are required are

(1) two β and γ detectors capable of monitoring the ranges of 0-20 mR/hour and 0-5 R/hour, respectively

(2) one γ detector capable of monitoring γ level ranges $\geq$100 R/hour

(3) one neutron detector capable of monitoring a range of 0-5 R/hour

(4) one α detector capable of monitoring a range $\geq$100 000 counts/min

Radiation safety personnel routinely monitor the air and water, conduct area smears, and monitor α, β, and γ radiation. Analysis of the reactor water pH and conductivity also is conducted. Any suspect radioactive waste materials are kept in process storage containers until they can be shipped offsite for disposal.

An emergency cabinet containing a minimum of two anti-contamination clothing sets, two full-face filter-type respirators, and one self-contained breathing apparatus is maintained.

9.4 Ventilation System

Supply air is from the general building system. The exhaust air system for the control center for the WNTR electric heating system is located in the upper level of the equipment room. The ventilation system is described in Section 6.2.

9.5 Fire Protection System

The WNTR fire protection system consists of heat-sensing elements, pull stations, smoke detectors, fire doors, CO_2 and ABC fire extnguishers, and audible alarms. All audible alarms (fire bells) have a battery backup power supply. Alarms are initiated from the training center, and transmitted to the emergency board located in the Zion Police Station.

An annual check of the detectors and alarms is conducted by an outside, independent contractor. Annual inspections and repairs of all fire extinguishers are conducted as well. Also, a monthly visual inspection and verification of the fire extinguishers is conducted. Annual fire protection drills as well as initial fire protection instructions are performed during personnel orientations to ensure that personnel are cognizant of the fire protection system and the associated responsibilities.

9.6 Compressed Air

A compressed air system in the facility equipment room supplies the compressed air necessary for maintaining the moderator-shield water dump valve in a closed position. The valve automatically opens when the air pressure is removed from the valve piston.

9.7 Water and Sewer Service

The WNTR water and sewer service is supplied by the Lake County Public Water District through the Zion City System.

9.8 Conclusion

The staff concludes that the auxiliary systems at the WNTR facility are well designed and are acceptable for their intended purposes.

10 EXPERIMENTAL PROGRAMS

The WNTR is used almost exclusively as a training tool. The experimental program is part of a formal program of familiarizing student operators with various reactor core parameters. Thus, the WNTR is not equipped with beam ports, thermal columns, or a pneumatic transfer system. Access to the core region is via the water shielding from the open tank top.

10.1 Training Experiments

The training operations consist of a formal program of demonstrations and operation practices using the following types of standard training experiments.

(1) reactor unloading
(2) fuel loading approach to critical 1/M method
(3) similated pressurized water reactor (PWR) core loading (poisoned core)
(4) rod bank 1/M approach to critical with poisoned core
(5) power run with poisoned core
(6) measurement of control rod worth in poisoned core
(7) fuel tube reactivity worth measurement
(8) neutron absorber reactivity worth measurement
(9) water hole reactivity worth measurement
(10) flux mapping by activation
(11) measurement of reactivity worth of the upper water reflector
(12) measurement of various reactor physics parameters

For the purpose of calibration and verification of the reactor's operational parameters, the following routine experiments may be executed periodically by the operating staff.

(1) flux mapping and power calibration
(2) measurement of radiation levels in and around the reactor
(3) measurement of temperature coefficient
(4) measurement of k_{excess}
(5) measurement of void coefficient
(6) measurement of fuel reactivity worth
(7) measurement of poison reactivity worth
(8) measurement of moderator reactivity effect

10.2 Experimental Review

Any reactor experiment of a nonroutine nature that is not covered by approved standard operating procedures is evaluated thoroughly by the operating staff, reviewed by the Reactor Safeguards Committee (RSC), approved by the facility management, and fully documented.

No training operation is allowed on a reactor experiment of a nonroutine nature. When a reactor experiment has been carried out successfully and all pertinent parameters have been determined, it may be classified as a routine experiment by the WNTR Facility Manager with the concurrence of the RSC.

The RSC reports to the Manager of the Nuclear Training Center and functions as a review and advisory committee in matters pertaining to the safe operation of the reactor facility. This committee is composed of five or more individuals collectively having a broad spectrum of expertise in radiation and/or reactor-related technology. (Additional details concerning the RSC can be found in Section 13.)

The limitations on experiments are specified in Section 4 of the Technical Specifications. In addition to ensuring safe operation in conformance with the license requirements, the review and approval process provides for personnel specifically trained in radiological safety and reactor operations to consider and recommend alternative operational conditions (such as different core positions, power levels, or irradiation times) that might decrease personnel exposure and/or the potential release of radioactive materials to the environment.

10.3 Conclusion

The staff concludes that the design of the facility, combined with the detailed review and administrative procedures applied to all reactor activities, is adequate to ensure that the reactor is used properly for training and that any experiments are unlikely to cause damage to the reactor systems or its fuel. Therefore, the staff considers that reasonable provisions have been made so that the experimental programs and use of the facility do not pose a significant risk of damage to the reactor.

11 RADIOACTIVE WASTE MANAGEMENT

Because of the low power level and limited operating schedule of the WNTR, there has been a negligible generation of radioactive waste. It is not anticipated that this pattern of waste generation will change significantly during the period of the license renewal.

11.1 Airborne Waste

The primary airborne waste that could be generated by the reactor operation is ^{41}Ar. The production and release of ^{41}Ar is controlled by the usage pattern of the reactor. The licensee's Technical Specifications limit the annual power generation to 200 kW-hours. This would indicate that the power generation in a typical week would be on the order of 4 kW-hours, based on 50 operating weeks per year and a relatively uniform operating schedule. Actual power generation has been on the order of 50 kW-hours per year or less. The extremely small amount of ^{41}Ar that may be generated during these limited reactor operations precludes any appreciable release to the reactor room.

11.2 Solid Waste

Potential solid waste generated as a result of reactor operation includes spent resins, contaminated paper and gloves, and occasional small activated components. This solid waste generation typically has contained sub-millicurie quantities of radionuclides per year. Solid waste is allowed to decay to levels consistent with disposal as nonradioactive waste or is packaged and shipped to an NRC-approved disposal site in accordance with applicable NRC and Department of Transportation regulations.

11.3 Liquid Waste

There are no radioactive liquids released from the reactor system. Any potentially radioactive liquids are collected in a storage drum and sampled and analyzed for gross activity before release to the sanitary sewer system.

11.4 Conclusion

Because ^{41}Ar is the principal radionuclide potentially released by the reactor to the environment during normal operations, the staff has reviewed the history, current practice, and future expectations of operations. The staff concludes that the potential exposures in unrestricted areas as a result of actual release of ^{41}Ar have never exceeded or even approached the limits specified in 10 CFR 20 when averaged over a year. Furthermore, the staff's conservative computations of the hypothetical doses beyond the limits of the reactor room give reasonable assurance that potential doses to the public as a result of ^{41}Ar would not be significant at the current licensed maximum power level.

The staff concludes, therefore, that the waste management activities of the WNTR facility have been conducted and are expected to continue to be conducted in a manner consistent both with 10 CFR 20 and with as-low-as-is-reasonably-achievable (ALARA) principles (see Section 12.1). Among other guidance, the staff review has followed the methods of ANSI/ANS 15.11, 1977, "Radiological Control at Research Reactor Facilities."

12 RADIATION PROTECTION PROGRAM

The WNTR has a structured radiation safety program with adequate staffing and appropriate detection equipment (1) to determine, control, and document occupational radiation exposures at its reactor facility and (2) to ensure compliance with applicable regulations concerning releases of radioactive materials to restricted and unrestricted areas.

12.1 ALARA Commitment

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

12.2 Health Physics Program

12.2.1 Health Physics Staffing

The routine health physics activities at the WNTR are performed by the operations staff. Nonroutine and emergency radiation safety support is available from the Commonwealth Edison Zion Nuclear Power Station health physics staff.

12.2.2 Procedures

Detailed written procedures have been prepared that address the health physics activities required for the WNTR facility. Copies of these procedures are readily available to all personnel.

12.2.3 Instrumentation

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

12.2.4 Training

All reactor operators are trained in health physics. The training program is designed to identify the particular hazards of each specific type of work to be undertaken and methods to mitigate their consequences. Retraining in radiation safety is provided as part of the operator requalification program. All reactor operators are given an annual examination on radiation safety practices and procedures.

12.3 Radiation Sources

12.3.1 Reactor

Sources of radiation directly related to reactor operations include radiation from the reactor core and low concentrations of short-lived radioactive material in the pool water.

The fission products are contained by the fuel's aluminum cladding. Radiation exposures from the reactor core are reduced to acceptable levels by water in the tank and concrete shielding of the reactor room.

12.3.2 Extraneous Sources

Sources of radiation that may be considered as incidental to the normal reactor operation but that are associated with reactor use include activated foils or samples.

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

12.4 Routine Monitoring

12.4.1 Fixed-Position Monitors

There is a criticality/area monitor near the fuel storage location with an audible alarm in the control room. An additional area monitor with a separate alarm is located near the control console. A third monitor in the reactor room serves as a criticality monitor and alarms if the gamma radiation activity increases to the preset level.

12.4.2 Experimental Support

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

12.5 Occupational Radiation Exposures

12.5.1 Personnel Monitoring Program

The WNTR personnel monitoring program is described in the Facility Operations Manual. To summarize the program, personnel exposures are monitored by the use of thermoluminescent dosimeters (TLDs) assigned to individuals who might be exposed to radiation. The TLDs are supplemented with self-reading ion chambers. In addition, instrument dose rate and time measurements may be used to administratively keep occupational exposures well below the applicable limits in 10 CFR 20.

All visitors are provided with self-reading ion chambers for monitoring purposes.

12.5.2 Personnel Exposures

The WNTR personnel annual exposure history for the last 5 years is given in Table 12.1. Exposures have been maintained well within applicable 10 CFR 20 guidelines and limits.

Table 12.1 Number of individuals in exposure interval

	Number of Individuals in Each Range				
Whole-Body Exposure Range (rem)	1979	1980	1981	1982	1983
No measurable exposure	236	323	383	408	416
<0.1	21	7	18	27	19
0.1 to 0.25	2	4	4	0	0
0.25 to 0.5	0	0	0	0	0
>0.5	0	0	0	0	0
Total number of individuals monitored	259	334	405	435	435

12.6 <u>Effluent Monitoring</u>

12.6.1 Airborne Effluents

A radioactive particulate air monitor in the reactor room is operated at least monthly while the reactor is in use to ensure that no unexpected airborne activity is being produced and to ensure against inadvertent release of radioactive materials in the facility's air to the unrestricted environment.

12.6.2 Liquid Effluents

As stated in Section 11.3, there are virtually no liquid wastes produced at the WNTR facility. On rare occasions, however, the coolant/moderator system must be drained to the unrestricted environment. Before release to the public sewers, representative samples are collected and analyzed to confirm that concentrations of radioactive materials in the liquid are below the values specified in 10 CFR 20.303.

12.7 <u>Environmental Monitoring</u>

The environmental monitoring program consists of several TLDs placed around the WNTR facility. The results indicate total readings of 100 ± 10 mrem per year at the site boundary, which compares well with the expected background level of about 100 mrem per year.

12.8 Potential Dose Assessments

Natural background radiation levels in the Zion area result in an exposure of about 100 mrems per year to each individual residing there. At least an additional 8% (approximately 8 mrems per year) will be received by those living in a brick or masonry structure. Any x-ray examinations or other medical diagnoses involving radiation will add to these natural background radiation levels, increasing the total accumulative annual exposure of those individuals.

Exposures from potential airborne or liquid releases from the WNTR facility are considered by the staff to be insignificant (see Section 11). The environmental monitoring program confirms that the upper limit for reactor-related exposures in the unrestricted area is less than 10 mrem per year for an individual who might remain at the site boundary continuously during the year.

12.9 Conclusions

The staff considers that radiation protection receives appropriate support from the WNTR administration. The staff concludes that (1) the radiation safety program is capable of supporting the training efforts, (2) the program is adequately staffed and equipped, (3) the procedures are integrated correctly into the research plans, and (4) surveys verify that operations and procedures are consistent with ALARA principles.

The staff concludes that the effluent monitoring programs conducted by WNTR facility personnel are adequate and acceptable to promptly identify significant releases of radioactivity and to predict maximum potential exposures to individuals in the unrestricted area. These predicted maximum levels are well within the applicable regulations and guidelines of 10 CFR 20.

Additionally, the staff concludes that the WNTR radiation protection program is acceptable because the staff has found no instances of reactor-related exposures of personnel above applicable regulations and no unidentified significant releases of radioactivity to the environment. Furthermore, the staff considers that there is reasonable assurance that the personnel and procedures will continue to protect the health and safety of the public.

13 CONDUCT OF OPERATIONS

13.1 Overall Organization

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

13.2 Training

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

13.3 Operational Review and Audits

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

13.4 Emergency Planning

10 CFR 50.54(q) and (r) require that a licensee authorized to possess and/or operate a research reactor shall follow and maintain in effect an emergency plan that meets the requirements of Appendix E of 10 CFR 50. At the staff's request, as part of the application for license renewal, the licensee submitted a plan following guidance contained in RG 2.6 (1979 For Comment Issue) and in ANS 15.16 (1978 Draft). By letter dated November 2, 1982, the licensee transmitted a revised Emergency Plan in fulfillment of the requirements of the applicable regulations. The Emergency Plan was reviewed by the staff against the applicable guidelines and was found to be acceptable.

13.5 Physical Security Plan

The WNTR has established and maintains a program to protect the reactor and its fuel and to ensure its security. The NRC staff has reviewed the Physical Security Plan and concludes that the plan, as amended, meets the requirements of 10 CFR 73.67 for special nuclear material of moderate strategic significance. WNTR's inventory of special nuclear material for reactor operation falls within that category. Both the Physical Security Plan and the staff's evaluation are withheld from public disclosure under 10 CFR 2.790(d)(1). Amendment No. 7 to the facility Operating License R-119, dated November 2, 1982, incorporated the Physical Security Plan as a condition of the license.

13.6 Conclusion

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

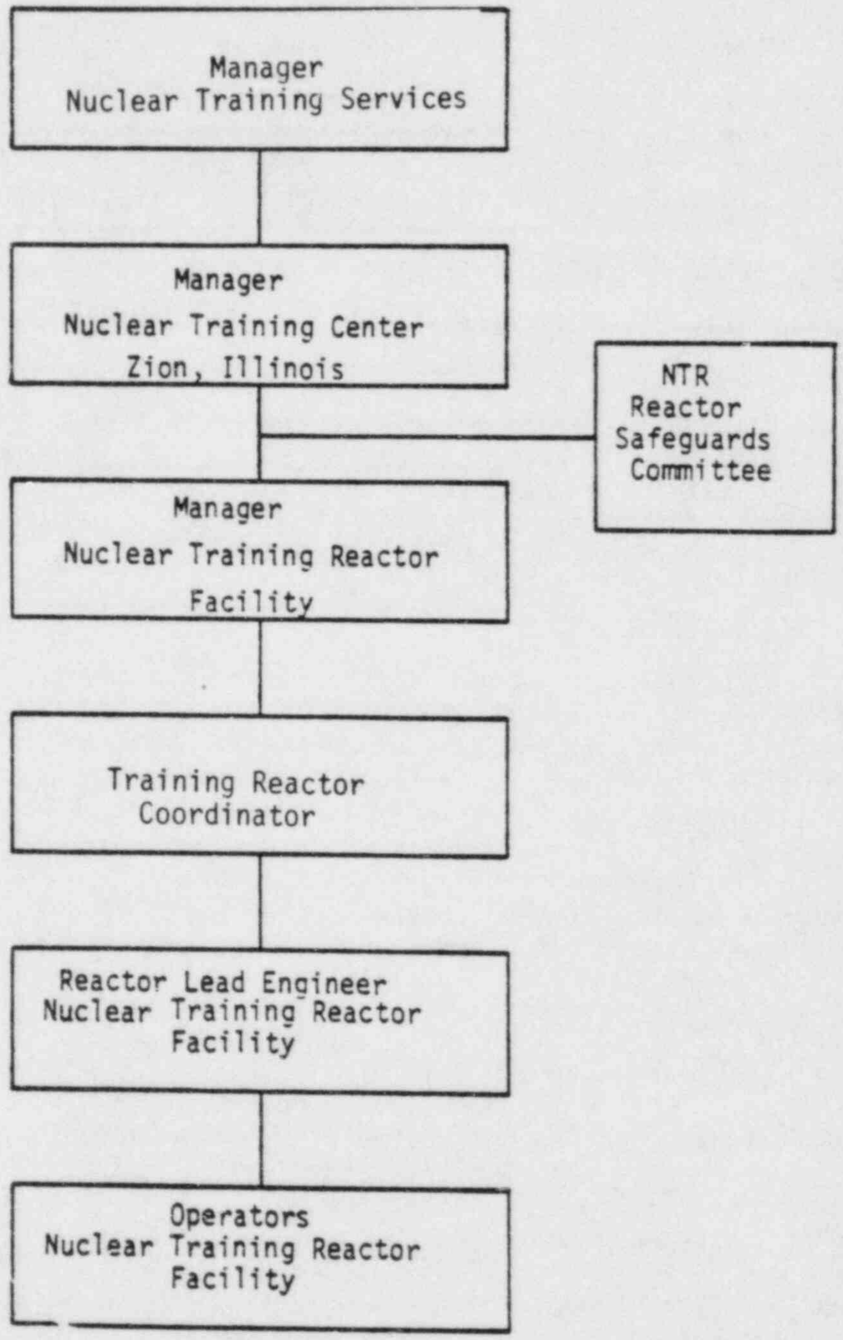

Figure 13.1 Operating staff organization

14 ACCIDENT ANALYSIS

In establishing the safety of the operation of the WNTR, the licensee analyzed potential accidents to ensure that these events would not result in significant hazards to the reactor staff or the public. The following accidents or effects were considered for evaluation and analysis.

(1) rapid insertion of reactivity (nuclear excursion)
(2) natural phenomena
(3) failure of experiments
(4) fuel element and irradiated material handling
(5) loss of coolant

Of these potential accidents or effects, the rapid insertion of reactivity (nuclear excursion) is the only one that can have a potential effect on the environment outside the WNTR training facility. For purposes of classification, the staff has designated this (the "nuclear excursion" accident) as the maximum hypothetical accident (MHA). An MHA is defined as an accident for which the risk to the public health and safety is greater than that from any other event that can be postulated mechanistically. Thus, the staff assumes that the accident occurs but does not attempt to describe or evaluate all the mechanical details or the probability of its occurrence; only the consequences are considered.

14.1 Rapid Insertion of Reactivity (Nuclear Excursion)

The step insertion of reactivity resulting from the removal of voids is discussed in Section 14.3. The only remaining way to obtain a rapid insertion of reactivity is through a ramp insertion of reactivity.

The largest ramp rate possible at the WNTR is during startup with all control rods being withdrawn at a maximum rate that will produce a 0.08% $\Delta k/k/s$ (0.10$/s) reactivity ramp rate. The licensee has made the following assumptions for the analysis of this accident, termed the MHA:

(1) The reactor is initially at $k_{eff} = 0.95$.
(2) The four shim rods are withdrawn simultaneously at a withdrawal rate (to produce a 0.10$/s ramp rate). The safety rod is assumed to be fully withdrawn.
(3) Failure of the count rate cutoff, decreasing-decade-level trip (linear-N channel), log-N period and level trips.
(4) Operator inattention.

Because the characteristics of the SPERT core and the WNTR core are somewhat similar (FSAR Table 7.5.1), the results of the SPERT-I A-17/28 core was utilized to evaluate the effects of the accident. Because the average void coefficient for the WNTR is larger than that for this SPERT core, less heat generation is required to form voids sufficient to terminate the accident (H. L. Witner, 1963).

The power excursion is assumed to begin at 1 mW and conclude with a power burst to 70 MW, at which time void formation would terminate the rise. Total energy released up to and including the peak of the burst is less than 5 MW-seconds. The reactor would then oscillate at power levels less than 1 MW until manually tripped. Maximum fuel temperature is 160°C, which is substantially less than the cladding melting point of 660°C.

The staff has reviewed the licensee's assumptions, methods of computations, and results related to the MHA. The licensee's results are comparable to the independent analysis by the staff. As a result, the staff agrees with the licensee's conclusion that no damage to the core is expected to occur; consequently, no fission products will be released. The radiation exposure received outside the WNTR room would be about 0.3 mrem for neutron and 1 mR for gamma. There will be no offsite radiation exposure.

14.2 Natural Phenomena

The licensee has considered the potential effects of natural phenomena such as floods, earthquakes, and tornados on the WNTR facility and concluded that the hazards to the reactor are negligible. The location is considered to be an area of minor seismic activity with only two moderate earthquakes (intensity VII on the Modified Mercalli Intensity Scale) occurring in the area since 1800. In the event of an earthquake of unexpected high intensity that may cause damage to the WNTR facility, the low fission product inventory in the fuel would represent an insignificant hazard to the area surrounding the facility. Historical meteorological data for Chicago and Milwaukee indicate that tornados rarely occur in this area and that the maximum expected wind speed is about 70 mph. Because the WNTR facility does not depend on electrical power to maintain the core in a safe shutdown condition, loss of power because of windstorms is of no concern.

Flooding is of no immediate concern because the facility elevation is higher than the maximum recorded wave run-up above lake level. However, if a flood did occur, the core would be shut down and maintained in safe shutdown during a flooded condition without electrical equipment. The staff agrees with the licensee's finding that the hazards from natural phenomena are negligible.

14.3 Core Collapsing Accident

As stated in Section 2.5.1, the area at the site includes filled solution cavities that may conceivably collapse. To determine possible consequences, it was assumed, that in some unidentified manner the reactor building could collapse into a solution cavity, the coolant would be rapidly drained and the fuel cladding would not be ruptured.

As indicated in Section 14.5, a loss of coolant is analogous to a manual moderator dump scram. Accordingly, the consequences would be insignificant.

If the core contents become rearranged, the core could become compressed into a smaller volume. Calculations in NUREG/CR-2198 indicate that such an event for a 100 kW reactor would result in a maximum temperature of approximately 250°C, well below the melting point of the cladding (660°C). Therefore, there would be no fission product release from this assumed accident.

14.4 Failure of Experiments

An experiment is any installed apparatus, device, or material within the confines of the reactor tank that is not a normal part of the assembly or any core loading that is not the normal core loading. For the reactor to be loaded, control rods must be present and are interlocked to prevent withdrawal, except with specific limitations. Even if the control rod with the highest worth of reactivity was not present or was fully withdrawn, the reactor would still remain subcritical by a margin greater than the 0.80% Δk/k (1.00$) (refer to Section 4.6.1) required in the Technical Specifications.

For all other experiments, the presence of apparatus, devices, or materials within the confines of the reactor tank represents a potential hazard because their sudden and unexpected removal could cause positive reactivity insertions. All equipment and apparatus are tested and inspected to verify that the reactivity addition, associated with equipment or apparatus failure, is kept below a value of 0.64% Δk/k (0.80$). All movable samples and devices are similarly limited to a maximum reactivity change of 0.20% Δk/k (0.25$). All experimental apparatus lighter than water is secured by two independent hold-down mechanisms. Thus, if an experiment failure occurred, the maximum positive reactivity insertion would be 0.64% Δk/k (0.80$). An independent calculation by the staff confirms the licensee's analysis and conclusion that the potential effects from a step insertion of 0.64% Δk/k (0.80$) (positive reactivity) will be less than that resulting from the "nuclear excursion" accident or MHA described in Section 14.1. Results from the SPERT tests indicate that insertion of this magnitude of excess reactivity will not cause damage to the reactor core or facility (H. L. Witner, 1963).

14.5 Fuel Element and Irradiated Material Handling

The possibility of a release of fission products resulting from an accident occurring during handling of a single fuel element or an irradiated material experiment is credible. The only associated hazard is radioactive releases that would be readily contained within the reactor room. Because of the small fission product inventory (~1.63 Ci) available in a fuel element, exposure to operating personnel would be minimal and cleanup is not expected to be significant. The staff agrees with the licensee that, in the event of a fuel handling or irradiated sample handling accident, the hazards to the public are negligible and that any hazards will be confined within the WNTR facility.

14.6 Loss of Coolant

Because a loss-of-coolant accident is analogous to the manual moderator dump scram, the consequences were deemed to be insignificant and not analyzed in detail.

14.7 Multiple or Sequential Failures of Safety Components

Of the several accident scenarios hypothesized for the WNTR, none produce consequences more severe than the MHA. The only multiple-mode failure of more severe consequences would be failure of the cladding of more than one fuel element. No credible scenario constructed by the staff has revealed a mechanism by which the failure of integrity of one fuel element can cause or lead to the failure of additional elements. Therefore, if the cladding of more than one fuel element should fail, the failures would either be random, or a result of the same primary event. Additionally, the reactor contains redundant safety-related measuring channels and control rods. Failure of all but two control rods and all but one safety channel would not prevent reactor shutdown to a safe condition. The staff review has revealed no mechanism by which failure or malfunction of one of these safety-related components could lead to a nonsafe failure of a second component.

14.8 Conclusions

The staff has reviewed the potential credible accidents and transients for the WNTR facility. On the basis of this review, the staff concludes that no credible accidents or transients would result in the release of significant quantities of fission products to the unrestricted environment. The maximum hypothetical accident is extremely unlikely, if not impossible. However, it does demonstrate the ability of the WNTR to withstand such an accident without damage to the reactor core. Therefore, the staff concludes that the design of the facility, together with the Technical Specifications, provides reasonable assurance that the WNTR facility can be operated with no significant risk to the health and safety of the public.

15 TECHNICAL SPECIFICATIONS

The licensee's Technical Specifications, evaluated in this licensing action, define certain features, characteristics, and conditions governing the continued operation of this facility. These Technical Specifications will be explicitly included in the renewal license as Appendix A. Formats and contents acceptable to the NRC have been used in the development of these Technical Specifications, and the staff has reviewed them using the ANS standard 15.1-1982 as a guide.

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

16 FINANCIAL QUALIFICATIONS

The WNTR is owned and operated by the Westinghouse Electric Corporation in support of its role in nuclear operator training and research. On the basis of financial information supplied by the licensee in its January 5, 1982, submittal, the staff concludes that funds will be made available, as necessary, to support continued operations and eventually to shut down the facility and maintain it in a condition that would constitute no risk to the public. The licensee's financial status was reviewed and found to be acceptable in accordance with the requirements of 10 CFR 50.33(f).

17 OTHER LICENSE CONSIDERATIONS

17.1 Prior Reactor Utilization

Previous sections of this SER concluded that normal operation of the reactor causes insignificant risk of radiation exposure to the public and that only an off-normal or accident event could cause some exposure. Even a maximum hypothetical accident (defined as one that is worse than can be mechanistically justified) would not lead to a dose to the most exposed individual greater than applicable guidelines or regulations (10 CFR 20).

In this section, the staff reviews the impact of prior operation of the facility on the risk of radiation exposure to the public. The two parameters involved are the likelihood of an accident and the consequences if an accident occurred.

Because the staff has concluded that the reactor was initially designed and constructed to be inherently safe, with additional engineered safety features, the staff must also consider whether prior operation might have caused significant degradation in these features. Furthermore, because loss of integrity of fuel cladding is the MHA, the staff has considered mechanisms that could increase the likelihood of failure. Possible mechanisms are (1) radiation degradation of cladding strength; (2) high internal pressure caused by high temperature, leading to exceeding the elastic limits of the cladding; (3) corrosion or erosion of the cladding, leading to thinning or other weakening; (4) mechanical damage as a result of handling or experimental use; and (5) degradation of safety components or systems.

The staff's conclusions regarding these parameters follow in the order in which they were identified above:

(1) The fuel in the core has been subjected to significantly less than 1% burnup of ^{235}U. This type of fuel has been in use at many other reactors and has experienced much greater burnup, with no observable degradation of cladding as a result of radiation.

(2) Because the reactor operates at a maximum power level of 10 kW, the temperature of the fuel or cladding does not exceed 200°C during normal operation. This is more than 400°C less than the melting points of the cladding.

(3) Water flow through the core is obtained by natural thermal convection, so the staff concludes that erosion effects as a result of high flow velocity will be negligible. High primary water purity is maintained by continuous passage through the filter and demineralizer system. With resistivity below about 200,000 ohm-cm, as limited by the Technical Specifications, corrosion of the aluminum cladding is expected to be negligible.

(4) The fuel is handled as infrequently as possible, consistent with periodic surveillance. Any indications of possible damage or degradation are investigated immediately. The only experiments that are placed near the

core are for training purposes; these experiments are repeated in different training sessions. Therefore, the staff concludes that loss of integrity of cladding through damage does not constitute a significant risk to the public.

(5) WNTR performs regular preventive and corrective maintenance and calibrations of safety-related components and replaces components as necessary. Nevertheless, there have been some malfunctions of equipment. However, the staff review indicates that most of these malfunctions have been random one-of-a-kind incidents, typical of even good quality electromechanical instrumentation, and the staff further concludes that the preventive maintenance program would lead to adequate indentification and replacement before significant degradation occurred.

17.2 Conclusion

On the basis of the above discussion, the staff concludes that there has been no apparent significant degradation of safety equipment and, because there is strong evidence that any future degradation will lead to prompt remedial action by WNTR personnel, there is reasonable assurance that there will be no significant increase in the likelihood of occurrence of a reactor accident as a result of component malfunction.

18 CONCLUSIONS

On the basis of its evaluation of the application as set forth in the previous sections, the staff has determined that

(1) The application for renewal of Operating License R-119 for its research reactor filed by the Westinghouse Electric Corporation dated December 11, 1981, as supplemented, complies with the requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's regulations set forth in 10 CFR, Chapter I.

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

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

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

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

19 REFERENCES

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

---, 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," May 1982.

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

---, 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.

Witner, H. L., et al., "Reactor Instrumentation and Test Procedures," SPERT-I Destructive Test Results, transactions of the American Nuclear Society, Vol. 6, no. 1, p. 137, June 1963.

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

Zion Station Preliminary Safety Analysis Report, Commonwealth Edison, Docket No. 50-295 and 50-304.

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12. SUPPLEMENTARY NOTES

Docket No. 50-87

13. ABSTRACT (200 words or less)

This Safety Evaluation Report, prepared by the Office of Nuclear Reactor Regulation of the U. S. Nuclear Regulatory Commission, is for an application filed by the Westinghouse Electric Corporation (WEC) for renewal of operating license R-119. The facility is owned and operated by the Westinghouse Electric Corporation and is located in the City of Zion, Illinois. The staff concludes that the reactor facility can continue to be operated by WEC without endangering the health and safety of the public.

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