WASHINGTON STATE UNIVERSITY

NOTICE OF RENEWAL OF FACILITY OPERATING LICENSE

AND

NEGATIVE DECLARATION

Docket No. 50-27

The U. S. Nuclear Regulatory Commission (the Commission) has issued Amendment No. 10 to Facility Operating License No. R-76, issued to Washington State University (the licensee), which renews the license for operation of the TRIGA reactor (the facility) located on the University's campus in Pullman, Washington. The facility is a research reactor that has been operating at power levels not in excess of 1000 kilowatts (thermal).

The amendment extends the duration of Facility License No. R-76 for twenty years from the date of issuance of this amendment.

The application for the amendment complies with the standards and requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's rules and regulations. The Commission has made appropriate findings as required by the Act and the Commission's rules and regulations in 10 CFR, Chapter I. Those findings are set forth in the license amendment. Notice of the proposed issuance of this action was published in the Federal Register on July 16, 1979 at 44 FR 41360. No request for a hearing or petition for leave to intervene was filed following notice of the proposed action.

The Commission has prepared an Environmental Impact Appraisal for the renewal of the Facility Operating License and has concluded that an Environmental Impact Statement for this particular action is not warranted because there will be no significant environmental impact attributable to the action.

For further details with respect to this action, see (1) the application for amendment dated May 15, 1979, as supplemented by filings dated May 15, 1979; May 29, 1979; June 4, 1979; June 21, 1979; February 4, 1981; March 3, 1981; and April 26, 1982; (2) Amendment No. 10 to License No. R-76 and (3) the Commission's related Safety Evaluation Report and Environmental Impact Appraisal. All of these items are available for public inspection at the Commission's Public Document Room, 1717 H Street, N.W., Washington, D.C.

A copy of items (2) and (3) may be obtained upon request from the U. S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Director, Division of Licensing.

Dated at Bethesda, Maryland, this 11th day of August 1982.

FOR THE NUCLEAR REGULATORY COMMISSION

H Bernard

Harold Bernard, Acting Branch Chief
Standardization & Special
Projects Branch
Division of Licensing

NUREG-0911

Safety Evaluation Report

related to the renewal of the operating license for the Washington State University TRIGA Reactor

Docket No. 50-27

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

May 1982

NOTICE

Availability of Reference Materials Cited in NRC Publications

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

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

2. The NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission,
   Washington, DC 20555

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

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

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

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

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

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

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

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

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

GPO Printed copy price: $4.75

ERRATA FOR NUREG-0911

SAFETY EVALUATION REPORT FOR

WASHINGTON STATE UNIVERSITY

Page 2-8, first paragraph in Section 2.7. Delete the last sentence in this paragraph beginning "the closest ..." and ending in "downwarp". Insert as the last sentences in the first paragraph the following: "Several faults have been mapped in the region which approach to within a few tens of kilometers from the site. These include the Vista and Wilma faults, which are associated with the Lewiston downwarp, and the Hite fault which approximately parallels the Blue Mountain anticling. These faults are interpreted to be inactive."

NUREG-0911

Safety Evaluation Report

related to the renewal of the operating license for the Washington State University TRIGA Reactor

Docket No. 50-27

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

May 1982

ABSTRACT

This Safety Evaluation Report for the application filed by the Washington State University (WSU) for a renewal of operating license number R-76 to continue to operate a research reactor has been prepared by the Office of Nuclear Reactor Regulation of the U.S. Nuclear Regulatory Commission. The facility is owned and operated by the Washington State University and is located on the WSU campus in Pullman, Whitman County, Washington. The staff concludes that the TRIGA reactor facility can continue to be operated by WSU without endangering the health and safety of the public.

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1 INTRODUCTION

The Washington State University (WSU) (licensee/applicant) submitted a timely application to the U.S. Nuclear Regulatory Commission (NRC) (staff) for renewal of the Class 104 Operating License (R-76) for its modified TRIGA research reactor by letter (with supporting documentation) dated May 15, 1979 for renewal of the operating license for 40 years. Although the licensee requested license renewal for a 40-year period, it is current staff practice to issue license renewals of 20 years for nonpower reactors. WSU currently is permitted to operate the reactor within the conditions authorized in past amendments in accordance with Title 10 of the Code of Federal Regulations, Paragraph 2.109 until NRC action on the renewal request is completed.

The staff technical safety review with respect to issuing a renewal operating license to WSU has been based on the information contained in the renewal application and supporting supplements, plus responses to requests for additional information. The renewal application includes: Physical Security Plan as supplemented through August 25, 1978; Technical Specifications as supplemented on May 15, 1979; Environmental Impact Appraisal Data as supplemented on May 15, 1979; Safety Analysis Report as supplemented on May 15, 1979; Reactor Operator Requalification Program; and Emergency Plan.* This material is available for review at the Commission's Public Document Room at 1717 H Street N.W., Washington, D.C.

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 WSU modified TRIGA reactor and to delineate the scope of the technical details considered in evaluating the radiological safety aspects of continued operation. This SER will serve as the basis for renewal of the license for operation of the WSU facility at steady-state thermal power levels up to and including 1 MW, and pulsed operation with step reactivity insertions up to 2.50$ (1.75 percent $\Delta k/k$). The facility was reviewed against the requirements of 10 CFR 20, 30, 50, 51, 55, 70, and 73, applicable Regulatory Guides (Division 2, Research and Test Reactors); and appropriate accepted industry standards (American National Standards Institute/American Nuclear Society (ANSI/ANS 15 series)). Because there are no specific accident-related regulations for research reactors, the staff has at times compared calculated dose values with related standards in 10 CFR 20, the standards for protection against radiation, both for employees and the public.

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*The Environmental Impact Appraisal Data and Safety Analysis Report (SAR) were used as basic review documentation, and are referenced throughout this report.

The staff technical safety review with respect to issuing a renewal operating license to WSU has been based on the information contained in the renewal application and supporting supplements, plus responses to requests for additional information. This material is available for review at the Commission Public Document Room at 1717 H Street N.W., Washington, D.C. This Safety Evaluation Report was prepared by James H. Wilson, Project Manager, Division of Licensing, Office of Nuclear Reactor Regulation, Nuclear Regulatory Commission. Major contributors to the technical review include the project manager and R. E. Carter (NRC staff), and J. Hyder, D. Whittaker, and A. Blackstock of Los Alamos National Laboratory (LANL) under contract to the NRC.

The WSU reactor has been in operation since March 1961. From 1961 to 1967 the reactor was fueled with MTR-type fuel elements and operated at a maximum power level of 100 kW. In 1967 the reactor was shut down and the core and control systems were modified so that the reactor could operate with TRIGA-type fuel. The orginal core grid box was retained and the MTR fuel elements were replaced with a special 4-rod cluster of TRIGA fuel rods designed to replace an MTR fuel element. From July 1967, to date, the reactor has operated as a modified TRIGA reactor with a maximum steady-state power level of 1 MW. In February of 1976 the core was loaded with a mixture of standard and FLIP* fuel.

The WSU reactor has operated for more than 20 years with an average annual use in the experimental programs of about 557 MW hours per year. In terms of radiation exposure of reactor components or production of radioactive material, this amount of operational use corresponds to about 70 working days per year at maximum authorized steady-state power.

TRIGA reactors--utilizing essentially the same kind of fuel, similar control rods and drive systems, and safety circuitry as at WSU--have been constructed and operated in many countries of the world. Among approximately 58 such reactors in operation, some since 1958, there have been no reported events that caused significant radiation risk to the public health and safety. Some other TRIGA reactors have annual MW hours of operation at least a factor of 10 greater than the WSU reactor, primarily because of different types of research programs.

1.1 Summary and Conclusions of Principal Safety Considerations

The staff evaluation considered the information submitted by the applicant, past operating history recorded in annual reports submitted to the Commission by the applicant, reports by the Commission's Office of Inspection and Enforcement, and onsite observations. In addition, as part of the licensing review, the staff obtained laboratory studies and analyses of several accidents postulated for the TRIGA-type reactor.

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

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*FLIP (Fuel Life Improvement Program) is a type of long-lived fuel developed by Gulf energy and environmental systems for TRIGA reactors.

(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 serious credible accidents and determined that the calculated potential radiation doses outside of the reactor room are not likely to exceed 10 CFR 20 doses in unrestricted areas.

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

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

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

(6) The financial data and information provided by the applicant are such that the staff has determined that the applicant has sufficient revenues to cover operating costs and to ensure protection of the public from radiation exposures when operations are terminated.

(7) The applicant's program for providing for the physical protection of the facility and its special nuclear material comply with the applicable requirements in 10 CFR 73.

(8) The applicant'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 applicant has submitted an Emergency Plan using guidance that was current at the time of license renewal application. The applicant has until November 3, 1982 to submit a revised Emergency Plan that follows new guidance developed since the WSU renewal request was tendered. This item is discussed further in Section 13.3.

1.2 Reactor Description

The WSU TRIGA is a heterogeneous pool-type reactor. The core is cooled by natural convection of light water, moderated by ZrH_x and water, and reflected by water and graphite. The core is located in a 242,000-liter above-ground pool which is, in turn, cooled and purified by external cooling and purification systems. Reactor experimental facilities include incore irradiation positions, a thermal column, and numerous beam tubes.

The existing reactor system operates with a mixture of standard and FLIP types of TRIGA fuel in the steady-state or pulsed modes. The maximum continuous steady-state power level is 1 MW and the maximum pulsed power level is 2400 MW. Standard TRIGA fuel contains $U-ZrH_x$ enriched in ^{235}U to less than 20 percent. FLIP TRIGA fuel contains $U-ZrH_x$ enriched in ^{235}U to 70 percent with 1.5 weight percent erbium as a burnable poison to offset the added ^{235}U. The reactivity worths of both types of fuel are about equal. The increased ^{235}U content of FLIP fuel along with the burnable poison yields a fuel that has a significantly larger core lifetime potential than standard TRIGA fuel.

The safety of the modified system comes from the large prompt negative temperature coefficient that is inherent in a water-moderated, $U-ZrH_x$ fueled reactor. The reactor has been operated safely for more than 6 years in its present configuration with a mixed FLIP and standard TRIGA core.

1.3 Reactor Location

The WSU TRIGA reactor building is located on the northeast corner of the WSU Campus at Pullman, in Southeastern Washington, about 8 km northwest of the Idaho state line on gently rolling terrain.

1.4 Shared Facilities and Equipment and Any Special Location Features

The reactor building is constructed of reinforced concrete and is attached to a laboratory complex dedicated primarily to nuclear science-related research. Some of these facilities are associated with reactor operations and use. Utilities such as municipal water and sewage, natural gas, and electricity are provided to the complex for joint use.

The reactor building has its own ventilation control system, capable of isolation, and dilution modes of operation, which exhausts air through an elevated stack located on the roof of the attached laboratory building. This stack also exhausts air from the reactor operating areas at a typical total flow of about 5000 cfm. The nearest occupied dwelling is about 400 m west of the reactor exhaust stack.

1.5 Comparison with Similar Facilities

The reactor core is similar to that of most of the 58 TRIGA reactors operating throughout the world, 27 of which are in the United States (24 are licensed by NRC, the other 3 by DOE). The instruments and controls are typical of NRC-licensed and other research reactors.

2 SITE CHARACTERISTICS

2.1 Geography

WSU is located in the southeastern corner of the State of Washington in the town of Pullman as shown in Figure 2.1. The town of Pullman, Washington, has a population of 23,500 and is located in Whitman County about 11 km from the Washington-Idaho border. In addition to the town of Pullman, the town of Moscow, Idaho, is located approximately 13 km east of the site just across the Washington-Idaho border. Moscow has a population of 17,700 and is the location of the University of Idaho. The Palouse region surrounding the towns of Pullman and Moscow is a rural agricultural area devoted to dry land farming.

The actual reactor site is 3.2 km east of the center of the town of Pullman and 1.6 km east of the main portion of campus. The site is surrounded by university-owned property for at least 0.4 km in all directions used for the grazing of livestock. The Moscow-Pullman airport is located 3 km east of the site and the closest occupied dwelling is 400 m west of the site.

2.2 Demography

The population distribution about the site in 500-m increments out to 3 km in eight directional segments is tabulated in Table 2.1. The population distribution was calculated for a typical day with the university students, faculty, and staff present on the campus. There are no permanently occupied dwellings within a radius of 400 m of the site. The staff concludes that there are no demographic characteristics associated with the site that would render it an unfit site for the WSU reactor.

Table 2.1 Population distribution around reactor site (number of residents per octant)

Distance, meters	N	NE	E	SE	S	SW	W	NW
0 - 500	0	0	0	0	0	0	35	0
500 - 1000	0	0	4	2	800	1032	66	92
1000 - 1500	0	0	0	0	27	1574	3393	233
1500 - 2000	0	0	0	15	18	5454	5280	0
2000 - 2500	0	0	0	0	0	700	2800	76
2500 - 3000	10	2	4	2	30	588	3200	280
3500	4	0	4	9	4	340	233	8
Total	14	2	12	28	879	9688	15,007	689

Figure 2.1 County map of the State of Washington

2.3 Nearby Industrial, Transportation, and Military Facilities

2.3.1 Transportation Routes

The Moscow-Pullman Municipal Airport is approximately 3.2 km northeast of the WSU reactor facility. No major airlines service the Moscow-Pullman airport and only small private planes and Cascade Airways, which operates very small planes, use this airport. The landing pattern for the northeast-southwest runway passes to the south of the WSU reactor facility.

2.3.2 Nearby Facilities

The reactor facility is located on the outskirts of a university campus in a small city. There are no heavy industries or large military installations nearby.

2.3.3 Conclusion

There is no heavy industry, or heavy air or ground traffic to constitute a threat to safe operation of the reactor. Therefore, the staff concludes that there is no significant risk from accidents to the reactor occurring as a result of activities associated with the military, industry, or transportation.

2.4 Meteorology

Pullman is situated at latitude 47° north of the equator, about midway between the equator and the North Pole. From May to August, when the sun remains above the horizon from 14 to 16 hours a day, Pullman receives more solar radiation than does the equator. In December, the sun rises only about 20° above the southern horizon at noon and is in the sky only about 8 hours. Therefore, the daily accumulation of solar radiation in winter is less for two reasons: (1) the days are shorter, and (2) the sun's rays, striking the earth at an angle, are spread over a larger area. Because of this great variation in energy intake, Pullman experiences pronounced differences in temperature and other weather conditions from summer to winter.

The latitude of Pullman is only one factor influencing the climate pattern at the site. Other factors are its location with respect to land and water areas, mountain barriers, and prevailing winds. Pullman is approximately 480 km inland from the Pacific Ocean; the Cascade Mountains, which average more than 2 km in height, separate Pullman from the coast. The combined effect of the distance from the ocean and the existence of the mountain barrier creates a climate with a continental characteristic. However, because the prevailing winds blow inland from the Pacific Ocean, winters are considerably warmer than otherwise might be expected 480 km inland at a latitude of 47° north. Winters in Pullman are characterized by cloudy skies and frequent snowstorms. On the average, the sun shines in Pullman only about 30 percent of the time during the winter months.

During the summer months, the westerly winds weaken and continental climatic conditions prevail; rainfall, cloud cover, and relative humidity are at their maximum. Summers in Pullman are characterized by warm clear days and cool nights. On the average, the sun shines in Pullman about 80 percent of the time during the summer months.

WSU is located in eastern Washington in a dry-land agricultural area, known as the Palouse region. The climate of this region is moderate, being a transitional region between the Columbia Basin and the mountains of Idaho. Precipitation and temperature data at the WSU campus have been accumulated since 1893 by the Department of Agronomy at the school.

A wind rose indicating the frequency of occurrence of winds at the site is given in Figure 2.2. It is to be noted that the prevailing winds are from a westerly direction and blow over Pullman and the campus toward the site. The major population density is upwind from the site about 57 percent of the time and downwind only about 21 percent of the time. Furthermore, about 79 percent of the time the wind blows in a direction in which there are no inhabitants for about 0.8 km from the site.

The average annual wind velocity is 16 km/hr. Winds in January, the high month, average 21 km/hr. Furthermore, the wind velocity was greater than 5 km/hr 94 percent of the time and greater than 8 km/hr 76 percent of the time. In general, one may conclude that there is almost always a light breeze blowing over the site.

The monthly average precipitation, monthly mean temperature, and monthly mean daily variation from minimum to maximum temperature at the site are tabulated in Table 2.2. The seasonal variations depicted in this table are a graphic representation of the climatic conditions that prevail at the site as previously described.

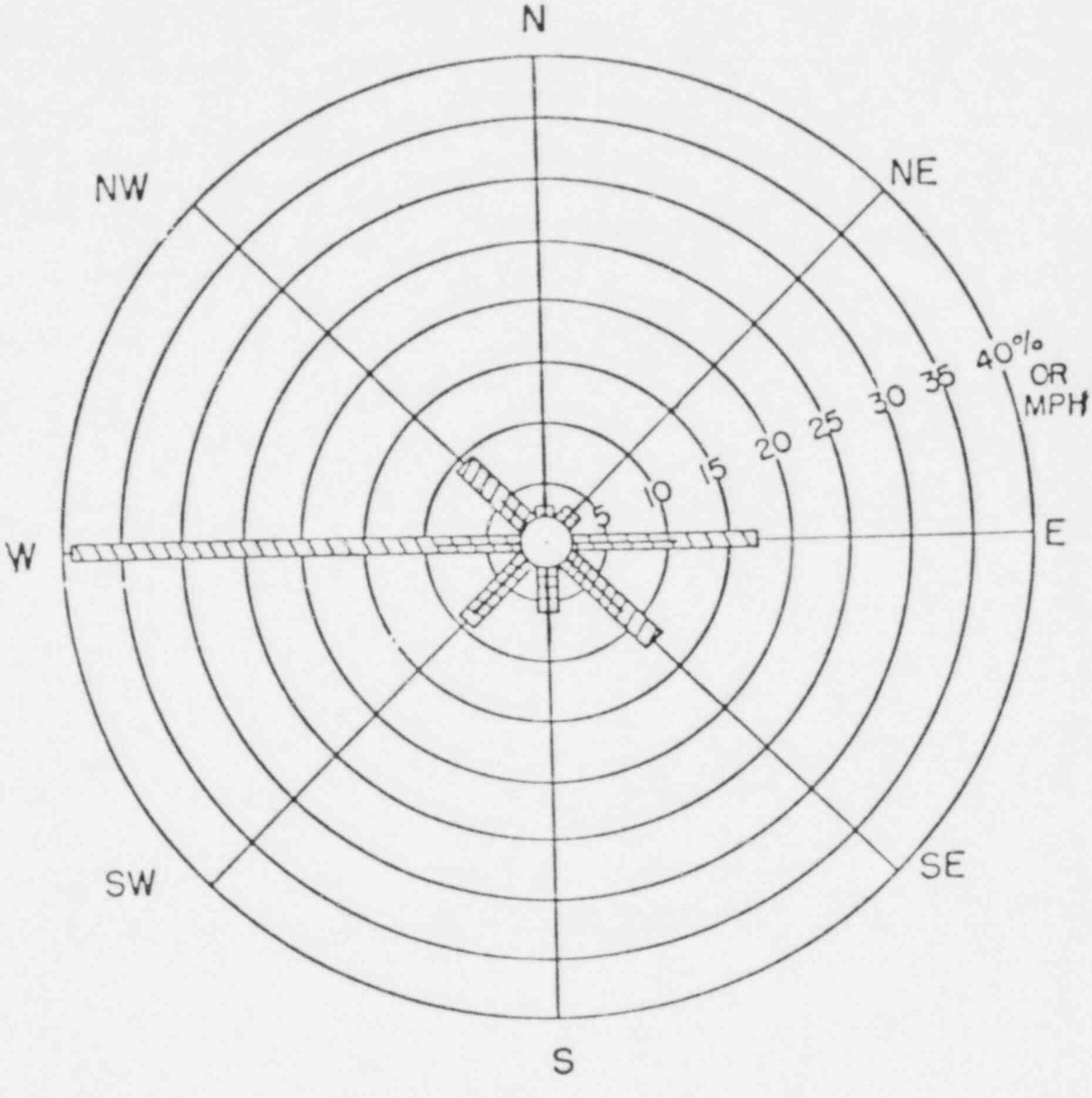
Quantitative data on temperature inversions in the vicinity of the site are nonexistent.

If the assumption is made that a temperature inversion can only be maintained with winds of below 3 km/hr, then inversions could occur about 6 percent of the time. The distribution of the low velocity winds further indicates that the population center west of the site would be only about 22 percent of the time during which inversions could possibly occur. The staff concludes that the meteorologic conditions of the site are acceptable for the relatively rapid dispersal of airborne radioactivity released from the reactor facility.

2.5 Geology

Pullman is situated in Eastern Washington near the eastern margin of the Columbia River Plateau.

The basalt of the Columbia Plateau is somewhat unique in that a large thickness of volcanic material accumulated in a relatively short period on the geologic time scale. The lava flows extended over a 160,000-km^2 area in the short span of about 3 million years, 16 to 13 million years ago. The total thickness of the basalt varies from 1000 m in the Pullman area to at least 2 km in the Pasco Basin. Several individual flows were enormous and involved on the order of 300 km^3 of lava.



(Hatched area in percent occurrence -
solid line is mean speed in mph)
- 1 mph = 1.61 km/hr -

Figure 2.2 Frequency distribution and mean wind speed at site from direction shown

Table 2.2 Monthly average precipitation, daily mean temperature, and mean daily minimum to maximum temperature difference, 1893-1970

Month	Precipitation, cm	Daily mean temperature, °C	Mean daily minimum to maximum, °C
January	6.78	- 2.6	5.7
February	5.33	0.2	6.7
March	5.38	3.8	8.4
April	3.78	8.5	10.8
May	3.71	12.7	11.8
June	3.91	15.7	12.7
July	0.99	19.9	15.7
August	1.32	19.1	15.3
September	2.74	14.3	13.0
October	4.85	10.0	10.4
November	6.27	3.2	6.7
December	6.96	0.1	5.7
Annual total precipitation - 49.50 cm			
Annual average temperature - 8.7°C			
Annual average difference between minimum and maximum temperatures - 10.2°C			

The basalt that flowed into the preflow terrain of the region progressively submerged the basement features and dammed up the well-established drainage systems. Numerous lakes were created along the margin of the growing basalt plateau. Weathering of the exposed basement uplands produced detritus materials that rapidly filled in the temporary Miocene lakes established by the advancing basalt. Such lacustrine deposits were subsequently buried by flows from renewed basaltic eruptions triggering a repetition of the accumulation cycle. The solidified lava flows were nearly horizontal, however, the lava evidently erupted from many different locations at different times so that individual flows are not continuous across the plateau. The original upper surface of the basalt was probably quite rough but very low in relief.

Following the cessation of the major igneous activity in early Pliocene times, the basalt and lacustrine deposits became subjected to moderate erosion as the drainage patterns began to develop. This initiated the dissection of the plateau surface. During the Pleistocene epoch the modified surface was capped with the loess of the Palouse formation and produced the rolling-hill topography of the region.

The Columbia River formation in the Pullman area is approximately 1000 m thick and consists of alternating layers of basalt and the silts and clays of the Latah formation. A geologic cross-section of the Pullman area is shown in Figure 2.3. The Palouse formation at the site is 35 to 55 m thick. Structurally the layers of basalt in the Pullman area have not been disturbed since their deposition. The major movements in this section of the Columbia Plateau have been the Lewiston downwarp and the westerly subsidence.

No known geologic hazards such as karst terrain, cavernous conditions, tectonic depressions, surface or subsurface subsidence or uplifts, or active volcanoes, are present at the site or in the immediate vicinity of Pullman. Also, there are no conditions present which could produce rockfalls, avalanches, floods, tsunami, mudflows, or permafrost at the site. The staff concludes that geologic formations at the site do not pose significant risks to the facility as to make the site an unacceptable location for the WSU reactor.

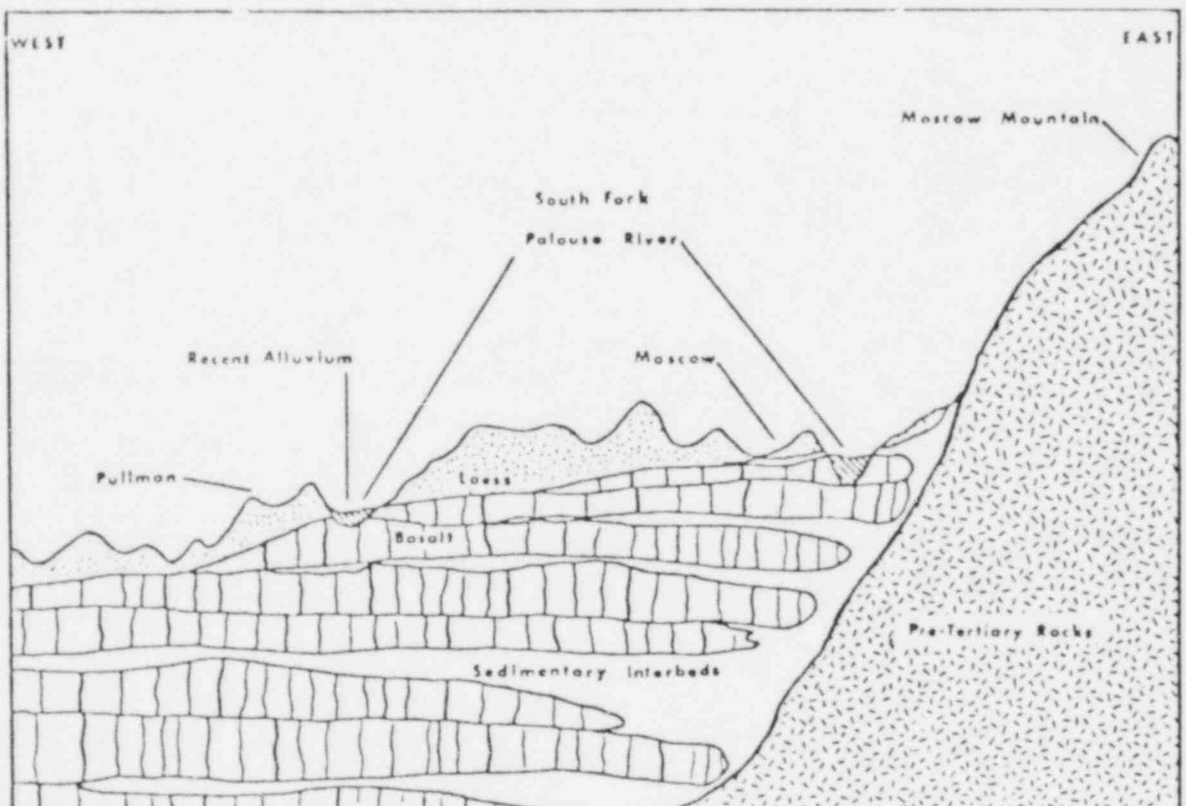


Figure 2.3 Schematic geologic section through the Pullman-Moscow basin (from Ichimura, 1978)

2.6 Hydrology

The main aquifers in the Pullman area are associated with the Latah formation interbeds between basalt flows as shown in Figure 2.3. Horizontal migration within an aquifer also may occur in the vesicular or porous top of the basalt layers. The cities of Pullman and Moscow obtain their water from deep aquifers over 200 m below the surface. Carbon-14 dating of the water from the deep aquifers indicates that no measurable recharge has occurred in recent times. Accordingly it is believed that a layer of impervious basalt about 100 m below the surface prevents the downward migration of surface waters.

Recharge of the shallow aquifers is believed to occur at the eastern end of the Moscow-Pullman basin where the basalts contact the pretertiary Moscow Mountain formation (see Figure 2.3). Additional recharge also occurs by infiltration from streams and precipitation waters. However, surface waters percolate slowly downward because of the high water retention capacity of the Palouse formation as well as the thickness of such soils. Accordingly liquids discharged at the reactor site in the event of an accident will not enter the local aquifer. In addition, there are no rivers or streams within 1 km of the site. The staff concludes that the hydrologic characteristics of the site do not render it unacceptable for the location of the reactor facility.

2.7 Seismology

There are no known significant faults in the immediate vicinity of Pullman. The closest active faults are in the vicinity of Walla Walla, Washington, some 110 km from Pullman. Several faults have been mapped within a few thousand meters of the site. These include the Vista and Wilma faults, which are associated with the Lewiston Downwarp, and the Hite fault, which parallels the Blue Mountain anticline. These faults are interpreted to be inactive.

Historically, the seismic activity within 100 km of the site is low, with infrequent earthquakes of low intensity and magnitude. Only two shocks have occurred at Pullman in recorded history, both of them were of low intensity.

Based on the geology of the Pullman area and the past seismic activity, the probability of the occurrence of significant earthquakes in the future can be said to be very small. The staff concludes that seismic hazards associated with the facility site are very small and pose no unacceptable risk to the reactor facility.

2.8 Conclusions

The staff has reviewed and evaluated the WSU reactor site for both natural and man-made hazards; it concludes that there are no significant risks associated with the site that make it unacceptable for the continued operation of the reactor.

3 DESIGN OF STRUCTURES, SYSTEMS, AND COMPONENTS

3.1 Wind Damage

Meteorological data indicate a low frequency of tornadoes and effects of tropical disturbances. The reactor pool is embedded in a monolithic reinforced-concrete shield, integrally constructed in a reinforced-poured-concrete building located partially below grade. Therefore, the staff concludes that wind or other storm damage to the WSU reactor facility is unlikely.

3.2 Water Damage

The reactor building is situated on the side of a well-drained hill above the flood plain. Therefore, the staff concludes that there is reasonable assurance that damage to the reactor by flood or groundwater is small.

3.3 Seismic-Induced Reactor Damage

The nearest seismic fault is some 110 km away, and the incidence of seismic activity has been infrequent. Furthermore, WSU is situated in an area of low probability of seismic activity. If there were catastrophic damage to the reactor building, the light-weight roof structures could cause only minimal damage to the submerged reactor core. Loss of integrity of the pool would allow release of the water, but, as described in Section 14.1.2, loss of coolant in itself does not lead to core damage. These considerations, in addition to the construction features of the reactor building, lead the staff to conclude that the risk of seismic damage to the reactor facility is small.

3.4 Mechanical Systems and Components

The mechanical systems of importance to safety are the neutron-absorbing control rods suspended from the superstructure, which also supports the reactor core. The motors, gear boxes, electromagnets, switches, and wiring are above the level of the water and readily accessible for testing and maintenance. An extensive preventive maintenance program has been in operation for many years for WSU to conform and comply with the performance requirements of the Technical Specifications.

The effectiveness of this preventive maintenance program is attested to by the small number and types of malfunctions of equipment over the years of operation. These malfunctions have almost exclusively been one of a kind (that is, no repeats) and/or of components that were fail safe or self-annunciating. Therefore, the staff concludes that there appears to be no significant deterioration of equipment with time or with operation. Thus, there is reasonable assurance that continued operation for the requested period of renewal will not increase the risks to the public.

3.5 Conclusion

The WSU reactor facility was designed and built to withstand all credible and probable wind and water damage contingencies associated with the site. A seismic event has a small likelihood of occurring and the consequences of such occurrence would be minimal; therefore, they need not be evaluated explicitly.

4 REACTOR

The WSU TRIGA reactor is a 1-MW pool-type research reactor using light water as the moderator, coolant, and shield and TRIGA-type solid fuel rods. It currently is authorized to operate either in the steady-state mode up to 1 MWt or in the pulse mode with a step reactivity insertion of up to 2.50$ (1.75 percent $\Delta k/k$).

The reactor core is immersed in a large, concrete, water-filled, open-topped pool. The pool is spanned by a manually operated bridge structure from which the core support structure is suspended. The core is situated in a grid box into which four-rod clusters of TRIGA fuel are positioned.

Reactor control is achieved by inserting or withdrawing neutron-absorbing control elements suspended from control drives mounted on the bridge. Heat generated by fission is transferred from the fuel to the pool water by natural convection cooling. The heat from the pool is dissipated to the atmosphere by means of a cooling-tower heat-exchanger arrangement. A mixed-bed demineralizer system maintains the purity of the pool water.

4.1 Reactor Core

The reactor core includes a rectangular array of approximately 100 fuel rods of which about half are FLIP rods; the remainder are standard TRIGA fuel rods. Also included are four control blades and their shrouds, a transient control rod and guide tube, and a startup neutron source. The fuel rods are contained in three- or four-rod elements that are supported by a cast-aluminum grid plate. The sides of the grid box are aluminum sheeting that direct the flow of cooling water through the core. The grid plate provides a 9-by-7 array of square holes for fuel elements and for graphite reflector elements in the outer rows on three sides. Two slots also are provided for the control blades. The current core contains 26 fuel elements, each of which is approximately 3 in. square and 37 in. long.

The fueled region of the core is an approximate rectangular, parallelepiped (reflector elements replace the fuel elements at two corners), that is 15 in. high by 30 in. long by 26 in. wide. A fully loaded operational core contains about 8.1 kg of ^{235}U.

4.1.1 Fuel Elements

The WSU reactor uses standard and FLIP TRIGA stainless-steel-clad cylindrical fuel rods in which enriched uranium is homogeneously mixed with a ZrH_x moderator.

FLIP fuel also contains 1.5 weight percent erbium as a burnable poison. The fuel part of each rod consists of a cylindrical rod of U-Zr-H_x containing 8.5 weight percent uranium with ^{235}U enriched to less than 20 percent in standard fuel and to 70 percent in FLIP fuel. The hydrogen-to-zirconium atom ratio of the fuel moderator material is approximately 1.7 to 1 in standard and

1.6 to 1 in FLIP fuel. The nominal weight of ^{235}U is 35 g in each standard fuel rod and 123 g in each FLIP rod. The fuel section of each rod is approximately 15 in. in length and 1.41 in. in diameter. Graphite end plugs (3.45 in. long) are located above and below the fuel section and function as neutron reflectors. The burnable poison (erbium) in each FLIP fuel rod compensates partially for reactivity changes caused by fission-product buildup and uranium burnup. At least one fuel rod position contains a special instrumented element into which thermocouples were fitted during fabrication. In all other respects, this rod is identical to standard or FLIP fuel rods. The thermocouples monitor the axial temperatures in the instrumented element. The fueled section and the graphite reflectors are contained in a 0.020-in.-thick type 304 stainless steel walled can. The can is sealed by welds with stainless steel fittings at the top and bottom. Each rod is about 30 in. long and weighs about 3.4 kg. As described above, the fuel rods are assembled in 2-by-2 bundles or elements with fittings at the bottom to permit location in the grid plate and at the top to attach lifting handles.

4.1.2 Control Elements

Power levels in the WSU reactor are regulated by three safety and one regulating blade-type control elements and a transient control rod. The poison section of each safety blade is a 3/8-in.-thick, 10.5-in.-wide, and 40.5-in.-long Boral sheet clad in aluminum. The regulating blade is a stainless steel sheet about 11 in. wide and 40 in. long. Each safety blade is guided throughout its travel by a shroud consisting of two thin aluminum plates 40 in. high, separated by aluminum spacers to provide a 0.125-in. water annulus around the blade. The shroud is latched to the sides of the grid plate and has small holes at the bottom to minimize the effect of viscous damping in the event of a scram.

The transient control rod is a 15-in.-long, solid borated-graphite cylinder contained in a 1.25-in.-diameter metal tube. It is contained in a special three-rod cluster of FLIP fuel in position D-5 near the center of the core. The transient rod is kept in position laterally by a guide tube inserted into the cluster.

4.1.3 Conclusion

The staff has reviewed the information regarding the reactor fuel core arrangement and reactivity control systems and found that design and performance capability of the components is adequate to ensure the safe operation of the reactor during the proposed licensing period.

4.2 Reactor Pool

The reactor core is positioned in the reactor pool under approximately 19 ft of light, demineralized water. This water serves as radiation shielding, a neutron moderator and reflector, and reactor coolant. The reactor pool is constructed of reinforced high-density and ordinary concrete and is rectangular in shape with the exception of two corners at one end, which are beveled. It is approximately 25 ft deep, 12 ft wide, and 28 ft long. The minimal wall thickness of the concrete pool is 18 in. The concrete is penetrated by a thermal column and a number of beam ports. The reactor pool contains approximately 65,000 gal of water. The natural thermal convection of this water disperses the heat generated in the core by the normal operations of the reactor, both steady state and pulsed. The pool water is pumped through an external heat exchanger system that ultimately disposes of the heat to the atmosphere.

4.3 Support Structure

A manually operated bridge structure spans the pool, and the reactor core support structure is suspended from it. The movable bridge is mounted on rails so that the bridge and reactor structure can be moved laterally from one position within the pool to another. The control element drives also are supported by the bridge structure. The core support structure, which is made of aluminum, supports the grid box into which the fuel bundles are inserted. The hollow corner posts of the structure serve as tubes for the nuclear instrumentation detectors. The reactor is normally operated in one of two positions: either at the 0.0 position, up against the thermal column, or 6 in. away from the thermal column, to limit production of ^{41}Ar.

4.4 Reactor Instrumentation

The WSU reactor instrumentation is similar to that found on research reactor installations at other institutions. Temperature measurements are made in the core by thermocouples fitted into a fuel rod. These measurements are indicated and recorded on the control console. Neutron flux measurements are made with a boron-lined compensated ion chamber (CIC) and a fission ionization chamber with indicators located on the control console. The reactor power level is determined from the CIC using a μμ ammeter and from the fission chamber using a wide-range channel. A gamma detector is used to measure the reactor power in the pulse mode of operation.

The reactor instrumentation is integrated into the overall control and instrumentation system, which is discussed in Section 7.

4.5 Biological Shield

The reactor core is shielded in the lateral direction by the reactor pool water and by the concrete walls of the pool. Vertical-direction shielding consists of approximately 19 ft of pool water above the core and about 3 ft of pool water and the concrete bottom of the pool below the core. The concrete walls of the pool vary in thickness from 18 in. at the top to 6 ft at the beam port level. Additional shielding is provided by a berm of soil against one side and one end of the pool structure. The staff concludes that the installed shielding of the WSU reactor is adequate to protect the health and safety of the public and the environment.

4.6 Dynamic Design Evaluation

The safe operation of a TRIGA reactor during normal operations is accomplished by the control rods and is monitored accurately by the core power-level detectors. A backup safety feature is the reactor core's inherent large negative temperature coefficient of reactivity resulting from an intrinsic molecular characteristic of the ZrH_x alloy at elevated temperatures. Because of the large prompt negative temperature coefficient, step insertions of excess reactivity resulting in an increasing fuel temperature will be compensated for rapidly and automatically by the fuel matrix. This will terminate the resulting excursion without any dependence on (1) the electronic or mechanical reactor safety systems or (2) actions of the reactor operator. This inherent characteristic of the U-ZrH_x fuel has been the basis for designing these reactors with a pulsing capability as one normal mode of operation. Similarly, because of the large negative temperature coefficient of reactivity, changes of reactivity resulting in a change in fuel temperature during steady-state operation will be rapidly compensated for by this special fuel mixture, thus limiting the reactor steady-state power level (GA-4314, 1980). In new FLIP fuel, most of the negative temperature coefficient of reactivity results from resonant neutron absorption in erbium. As the erbium burns out, the prompt temperature coefficient decreases in magnitude while retaining its qualitative characteristics (GA-9064, 1970). Abnormal operations (accidents) are discussed further in Section 14.

4.6.1 Excess Reactivity

Excess reactivity in the WSU reactor core is now limited by Technical Specifications to 8.00$ (5.6 percent $\Delta k/k$). This amount provides for the negative power coefficient of reactivity of 1 MW, the negative reactivity effect of xenon at equilibrium at 1 MW, and about 2.0 percent additional for experiments and operational flexibility. Although limiting both the minimum shutdown margin (Section 4.6.2) and the total excess tends to overconstrain the reactor operation, it helps ensure that the full length of the fuel rods comprise the reactor being used. This ensures that the SAR analyses are applicable to the operational core.

Recently, another research reactor, using mixed standard and FLIP U-ZrH_x fuel in a geometry similar to that at WSU, experienced fuel rod damage without loss of cladding integrity. (Fuel damage in this case was limited to a blister and accompanied by fuel rod bowing.) The analyses and evaluation of that event indicate that WSU reactor core geometry and operational schedules are sufficiently different that the same type of malfunction is not likely to occur in the near future.

4.6.2 Shutdown Margin

The Technical Specifications state (Section 3.2):

> the shutdown margin provided by control elements shall be 0.25$ or greater with:
>
> a. the highest worth nonsecured experiment in its most reactive state,
>
> b. the highest worth control element and the regulating element (if not scrammable) fully withdrawn, and
>
> c. the reactor in the cold critical condition without xenon.

Because the regulating blade currently cannot be scrammed, this specification must be met with it fully withdrawn. The sum of the reactivity worths of all experiments in the reactor and the associated experimental facilities is limited by Technical Specifications to 5.00\$ and that of any single experiment to 2.00\$. All of these limits are applicable for any and all fuel loadings and reactor operating conditions.

The change in reactivity resulting from full operational withdrawal of a safety control blade ranges from 2.54\$ to 4.39\$ (3.1 percent $\Delta k/k$). The change in reactivity caused by complete operational withdrawal of the transient control rod is approximately 3.50\$. Full operational withdrawal of the regulating blade causes a reactivity change of about 0.44\$ (0.30 percent $\Delta k/k$).

The excess reactivity of the current WSU TRIGA reactor core is approximately 6.00\$. The shutdown margin of this core with the highest worth blade and regulating blade fully withdrawn is: (2.54 + 3.57 + 3.45) - 6.00 = 3.56\$. With all control blades inserted, this core is subcritical by 8.39\$.

Therefore, the current loading complies with the minimum shutdown margin limit in the Technical Specifications and permits performing experiments of total positive reactivity worth up to about 3.30\$ (2.4 percent $\Delta k/k$). If experiments of total positive reactivity worth equal to 5.00\$ are performed, the core loading must be limited to 4.30\$ (3.0 percent $\Delta k/k$) excess reactivity.

4.6.3 Conclusion

The staff concludes that the inherent large, prompt, negative temperature coefficient of reactivity of the $U\text{-}ZrH_x$ fuel moderator provides a basis for safe operation of the WSU reactor in the steady-state mode and is the essential characteristic supporting the capability of operation of the reactor in a pulse mode.

Furthermore, the staff concludes that with an excess reactivity of no more than 8.00\$ (5.6 percent $\Delta k/k$) and experiments with positive reactivity worth less than 3.30\$ (2.4 percent $\Delta k/k$) or other reactivity combinations totaling no more than 9.30\$ (6.5 percent $\Delta k/k$) positive reactivity, the worth of the WSU control rods will ensure a shutdown margin within Technical Specifications even if the most reactive control rod were operationally withdrawn from the core.

4.7 Functional Design of Reactivity Control System

4.7.1 Standard Control Element Drives

The drive units for the standard control rods are reversible electric motors with an integral worm-gear mechanism. Drive force on the blades is limited by means of a slip clutch on the output shaft to approximately 75 lb. The safety blades are attached to their drive mechanisms by use of electromagnets. If for any reason the electromagnets are deenergized, the safety blades are released and fall by action of gravity into the reactor core within 0.7 second, resulting in a reactor scram.

4.7.2 Transient Control Rod Drive

The drive unit for the transient rod is a combination pneumatic-electromechanical system that allows the reactor operator to use the transient rod as a control rod. The pneumatic portion of the drive system consists of an accumulator tank, air compressor, solenoid valve, pneumatic lines, and actuating piston. Compressed air is used to drive the transient rod up out of the core. If the air supply is interrupted, the rod falls by gravity into the core. The electromechanical portion of the drive consists of an electric motor, a ball-nut assembly, a threaded air cylinder, and worm-gear drive assembly. The threaded air cylinder can be raised or lowered independently of the piston and control rod by means of an electric drive. This controls the upper limit of the transient rod travel. This system is discussed in greater length in Section 7 of this report.

4.7.3 Scram-Logic Circuitry

The WSU reactor is equipped with a scram-logic system that receives signals from core instrumentation (neutron flux detectors and thermocouples). A wide range of scram modes is built into the overall logic circuitry. The scram modes include those listed in Table 4.1. Additional details of the scram are provided in Section 7.

Table 4.1 Scram modes in overall logic circuitry

Scram	Mode
Manual scram	Initiated at the discretion of the reactor operator.
Automatic scram	
High voltage monitor	Scrams on loss of high voltage to the power instrumentation channels.
Period scram	Scrams of reactor period less than 5 seconds. This circuit is provided for training purposes only and is not required by the Technical Specifications.
Preset timer	Transient rod scram 15 seconds or less after pulse initiation.
Fuel temperature	Scrams if fuel temperature exceeds 500°C. This circuit also scrams the reactor if a thermocouple fails. An open thermocouple produces a high-temperature scram. A shorted thermocouple produces a low temperature scram.
Power level	Scrams if the reactor power level exceeds 125 percent of full licensed steady-state power.

4.7.4 Conclusion

The WSU reactor is equipped with safety and control systems typical of most nonpower reactors. Therefore, the staff concludes that there is sufficient redundancy of control rods so that the reactor can be shut down safely even if the most reactive control rod fails to insert upon receiving a "scram" signal. The power level sensors are firmly attached and move with the core. Furthermore, independent sensors of power level--fuel temperature and neutron flux density--provide scram redundancy to mitigate consequences of single malfunctions.

The manual scram circuit operates through the scram logic system, removes electrical power, and is designed so that there is reasonable assurance that single-point failure will not render it inoperable.

In addition to the active electromechanical safety controls for normal and abnormal operation, the large, prompt, negative temperature coefficient of reactivity inherent in the U-ZrH_x fuel moderator discussed in Section 4.7 provides a unique backup safety feature. The reactor shutdown mechanism of this fuel terminates reactor transients that produce large increases in temperature and will limit steady-state power level. Because this inherent shutdown mechanism acts to limit the magnitude of a possible transient accident, it would mitigate the consequences of such accidents and can be considered to be a fail-safe safety feature.

In accordance with the above discussion, the staff concludes that the reactivity control systems of the WSU reactor are designed and function adequately to ensure safe operation and safe shutdown of the reactor under all normal operating conditions.

4.8 Operational Procedures

WSU has implemented a preventive maintenance program that is supplemented by a detailed preoperational checklist to ensure that the reactor is not operated at power without all of the safety-related components fully operational.

The reactor is operated by trained NRC-licensed personnel in accordance with explicit operating procedures, which include specified responses to any reactor control signal. All proposed new experiments involving the use of this reactor are reviewed by the WSU Reactor Safeguards Committee for potential effects on the reactivity of or damage to the core, as well as for possible effects on the health and safety of employees and the general public.

4.9 Conclusions

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

The staff review of the WSU reactor facility has included studying its specific design and installation, its control and safety instrumentation, and its specific preoperational and operating procedures. As noted earlier, these features are similar to those typical of other research reactors operating in many countries of the world, more than 60 of which are licensed in the United

States by NRC. Based on the review of the WSU reactor and experience with these other facilities, the staff concludes that there is reasonable assurance that the WSU reactor is capable of safe operation, as limited by its Technical Specifications, for the period of the license renewal.

5 REACTOR COOLANT AND ASSOCIATED SYSTEMS

The reactor coolant at WSU is demineralized light water, which is used to cover the reactor core in a large pool. The heat generated within the fuel during operation is transferred to the pool water by natural convection heat transfer. The heated pool water is pumped into the tube side of a conventional shell-and-tube heat exchanger and the shell side is connected to a cooling tower where the generated heat is dissipated to the atmosphere through the latent heat of vaporization of water. The primary side of the heat exchanger is maintained at a lower pressure, relative to the secondary side, to ensure that any leakage through faulty tubes is from the secondary to the primary.

5.1 Primary Cooling System

The primary cooling system is composed of the reactor pool, the primary coolant pump, the heat exchanger, and the demineralizer. Also included in the system are siphon breaks, which prevent draining of the reactor pool in case of pipe rupture as well as the siphoning of makeup water back into the public water supply. The system also is provided with instruments that allow the reactor operator to monitor water pressure, temperature, and conductivity at various points in the system from the control room. An alarm sounds in the control room if the power to the pump is lost.

5.2 Secondary Cooling System

The secondary cooling system consists of the shell side of the heat exchanger, the secondary pump, and the cooling tower. The system is provided with a thermostatically controlled heater to prevent the cooling water in the cooling tower sump from freezing during cold weather. The secondary pump motor is monitored for loss of power.

5.3 Nitrogen-16 Diffuser

Some of the oxygen present in the pool water is activated to ^{16}N by a fast neutron (n,p) reaction as the water passes through the core. To reduce the dose rate on the bridge caused by the upward migration of ^{16}N, a diffuser system consisting of a centrifugal pump and discharge nozzle was installed. This system pumps water from near the surface of the pool and discharges it downward and across the top of the core. The diffuser is manually actuated at power levels greater than 100 kW. The net result is an increase in the transport time of ^{16}N to the surface and a significant reduction of the ^{16}N-related dose rate at the bridge level.

5.4 Primary Coolant Purification and Makeup System

The pool water makeup and demineralizer system consists of the reactor pool, the mixed-bed demineralizer unit, a float switch, and a solenoid valve. Also included in the system is a demineralizer system that supplies makeup water to the purification system to compensate for pool evaporation. The float switch and solenoid valve automatically maintain the pool water level. The mixed-bed demineralizer is monitored for electrical conductivity and discarded rather than regenerated when depleted or spent.

The principal long-lived radionuclide in the pool water not rapidly removed by the water cleanup system is ^3H. The average concentration is several orders of magnitude below the limit specified in 10 CFR 20 for release to unrestricted areas.

5.5 Conclusion

The staff concludes that the overall cooling system at the WSU reactor is of proper size, design, condition, and maintenance level to ensure adequate cooling of the reactor under both steady and pulsed operating conditions at the power levels specified in the WSU operating license.

6 ENGINEERED SAFETY FEATURES

The only engineered safety system associated with the WSU reactor facility that is not directly associated with reactor control is the ventilation system. The only significant airborne radioactive materials formed as a result of normal reactor operations are ^{41}Ar and ^{16}N.

6.1 Ventilation System

The reactor pool area has a ventilation system that is separate from that of the rest of the Radiation Center complex. Under normal conditions air enters the reactor pool area through two supplies, a 3000-cfm fan and a 1350-cfm fan. The reactor area is maintained at a slight negative pressure by a 4500-cfm exhaust fan. This ensures that air flows from clean areas (such as offices) to potentially contaminated areas (reactor and beam room) and up the Radiation Center stack.

The reactor room/control area is connected to the rest of the Radiation Center complex by two doors to the hallway. There are two air-supply dampers to the reactor room and two exhaust dampers from the room; the damper on the dilution system is normally closed.

In the event of the release of airborne radioactivity within the reactor room, the continuous air monitor alarm triggers a signal that automatically closes the open dampers and opens dampers in the dilution mode, whereby 300 cfm is drawn from the reactor area through an absolute filter and discharged with an additional 1700 cfm of dilution air through the Radiation Center stack. In the event of a scram, the ventilation system automatically shifts to the isolation mode.

All of the dampers are spring loaded to shut in the event of a loss-of-control air pressure or electrical power. In the event of loss of electrical power, an interlock at the control console must be reset to allow restart of the ventilation system. Visual alarms indicate failure of an exhaust fan or loss of flow of the reactor building air to the stack.

6.2 Conclusion

The reactor building ventilation system equipment and procedures are adequate to control the release of airborne radioactive effluents in compliance with regulations and to minimize releases of airborne radioactivity in the event of abnormal or accident conditions. Therefore, the staff concludes that the public will be adequately protected from airborne radioactive hazards related to reactor operations.

7 CONTROL AND INSTRUMENTATION

Basically, the control and instrumentation system at the WSU reactor consists of a primary system with controls and instrumentation that are concerned with the reactor itself and with the safe control and monitoring of radioactivity; there is a supplementary system that is concerned with various processes such as water demineralization. Both systems are interlocked through the scram-logic circuitry to form the overall facility control and instrumentation system. From an engineering viewpoint, the control and instrumentation system at the WSU reactor is well designed and maintained. All wiring that is necessary for the safe operation of the facility is located in conduit or cable trays to protect it from physical damage. All power supplies for the instruments are common phase, and all circuits contain solid-state devices for reliability and ease of maintenance. Indicators are placed on the control console facilitating operator readability and accessibility.

Each scram function is represented with a dual-colored indicator lamp mounted on the control panel that displays the status of the scram circuit. This enables the reactor operator to immediately and positively determine the cause(s) of a scram.

All essential relays and terminal boards are mounted on slideout trays for easy maintenance. Instruments and control circuits are essentially free from ground-loop disturbances and extraneous electrical noise, and the control console layout reflects considerations of human engineering. The relays, amplifiers, and power supplies used in the system exceed minimum system performance requirements. The individual components of the control and instrumentation system are discussed in the following sections.

7.1 Control Systems

7.1.1 Primary Reactor Control

Control over the reactor is achieved by inserting and withdrawing neutron-absorbing control elements by use of control drives mounted on the reactor support structures. The control elements are the blade type and are suspended by electromagnets so that any power failure or other malfunction will result in the control elements falling into the core by gravity, resulting in a reactor scram. The control rods and the transient rod are controlled from the control room by use of electromechanical drive systems discussed in Section 4.8.

7.1.2 Primary System Prevents

A total of four primary system "prevents" is provided by the interlock and scram circuitry. The prevents are designed to preclude the possibility of uncontrolled reactor operation. The four primary system prevents are

(1) The control rod withdrawal prevent is provided through the pulse-mode switch and prevents the withdrawal of the control rods while the reactor is in the pulse mode.

(2) The 2-kW pulse prevent interlock prevents the initiation of a pulse above 2 kW steady state and is achieved through the wide-range power channel.

(3) The low-count withdrawal prevent is achieved through the wide-range power channel and prevents withdrawal of the control elements when the neutron count is less than 2 counts per second.

(4) The transient rod air-supply prevent interlock acts through the transient rod control circuitry and prevents pressurization of the transient rod pneumatic drive unless the transient rod is fully inserted in its down position.

7.1.3 Supplementary Control Systems

These control systems are designed to control the various processes involved in reactor operation but do not directly relate to safety. Included in this category are the pool water makeup system and the primary and secondary cooling pump controls.

7.1.4 Control Interlock System

As stated earlier, both the primary and supplementary control and instrumentation systems are interlocked to form the overall system. The control interlock system consists of circuitry designed for use in steady-state reactor operation and additional circuitry designed for use in pulse-mode operations.

7.2 Instrumentation Systems

The instrumentation system of the WSU reactor consists of both nuclear and nonnuclear detecting devices and recorders. The instrumentation is interlocked with the control circuitry by way of the scram-logic circuitry.

7.2.1 Nuclear Instrumentation

The nuclear instrumentation at WSU includes one compensated ion chamber and one fission chamber located in the core support structure near the core. Also included is a gamma radiator monitor located in the pool above the core. These instruments are coupled, respectively, to the linear-indication channel, the wide-range channel, and the pulse-power channel.

Instrumented fuel elements contain thermocouples that are connected to the scram system.

Additional nuclear instrumentation includes the continuous air-monitoring system (Figure 7.1) and the gaseous-effluent-monitoring system (Figure 7.2). All the nuclear instrumentation outputs are indicated and recorded in the control room and are connected to the alarm system. In addition to the instrumentation mentioned above, the facility is provided with five area monitors with indications and annunciators in the control room.

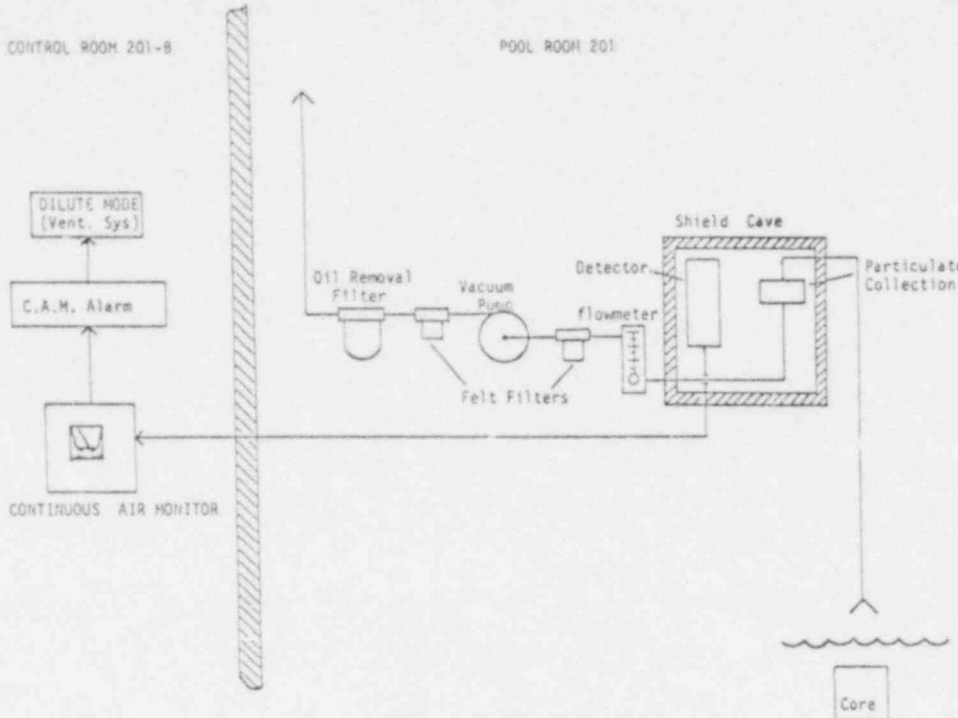


Figure 7.1 Continuous air-monitoring system

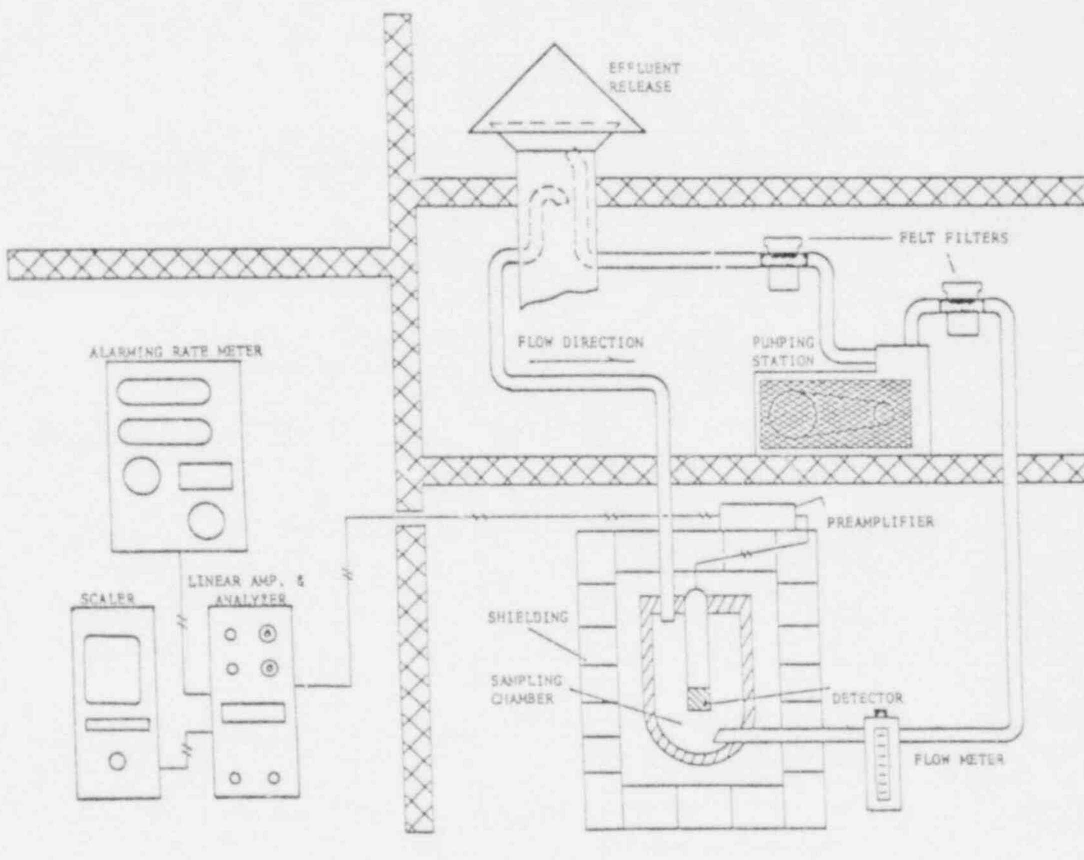


Figure 7.2 Gaseous-effluent-monitoring system

7.2.2 Supplementary Instrumentation

In addition to the primary instrumentation mentioned in Section 7.2.1, there is a wide variety of other instrumentation in use at the WSU reactor. Pool water temperatures, water flow rate, water conductivity, air flow, and waste water radiation levels are all parameters that are measured at the facility. In addition, a closed circuit television system is used to monitor the beam room and the radiochemistry laboratory.

7.3 Alarm and Indicator Systems

Alarms and/or indicators are provided in the control room as indicated in Table 7.1.

Table 7.1 Alarms and indicators

Unit	Set point	Visible	Audible	Location
Seismograph	0.05 g	X	X	Control room
Short period	5 sec	X	X	Control console
HV failure	590 V	X	X	Control console
High power	122%	X	X	Control console
Fuel temperature	500°C	X	X	Control console
High radiation	100 mR/hr	X	X	Control console
CAM	2000 cpm	X	X	Control console
A41 level	6700 cpm	X	X	Control console
Stack	2000 cpm	X	X	Control console
Neutron flux	110%	X	X	Control console
Pool level	6-in. drop	X	X	Control console
Pool conductivity	1 μmho	X	X	Control console
Low air pressure	70 psi	X	X	Control console
Blade disengage		X	X	Control console
Sample monitor	100 mR/hr	X	X	Control console
Beam port plugs		X	X	Control console
Bldg. evacuation	100 mR/hr	X	X	Control console
Vent. air flow	Flow/no flow	X		Auxiliary panel

7.4 Conclusion

The control and instrumentation system at the WSU reactor employs redundancy and is suited for measuring and monitoring all parameters required by current regulations. It is the staff's opinion that the control and instrumentation system is adequate to ensure the safe operation of the reactor within the context of current Technical Specifications and license conditions for the duration of the licensing period. The safety-related instrumentation fails into a safe mode, causing the reactor to shut down safely, and reactor restart is precluded by interlocks until the malfunction is repaired.

8 ELECTRICAL POWER

8.1 Main Power

Main power to the WSU reactor is provided by three transformers located near the facility. The power is standard commercial 3-phase ac and is filtered by a 20-amp "K"-type noise filter. Part of this filtered power remains 3-phase and is used to drive the facility ventilation system and the air compressor system. Another fraction of the power is reduced to 2-phase which is used to drive the control rod drive motors. The remaining power is fed into a large stepdown transformer that reduces the voltage to 24 V to provide the input power to all the control and instrumentation dc power supply circuits. This voltage step-down greatly reduces the effects of ac power line fluctuations. In addition, the reactor power-range detector circuit, which requires a high voltage input, is protected from line voltage drop by a low/high-voltage trip that scrams the reactor in the event that the voltage to the circuit falls below a given value.

8.2 Emergency Backup Power

The reactor control system and the facility ventilation system are not provided with emergency backup power because the reactor automatically scrams upon loss of ac power. However, by providing battery backup emergency power to the following systems, operations personnel can carefully monitor and determine the following safety-related parameters of the facility.

- Area radiation monitors
- Building evacuation alarm
- Seismograph monitor
- Pool water level monitor
- Building security system
- Emergency lighting

8.3 Conclusion

The staff concludes that the primary and emergency electrical power provided to the reactor facility are adequate to ensure safe operation and shutdown of the reactor.

9 AUXILIARY SYSTEMS

9.1 Ventilation System

The ventilation system is considered an engineered safety feature and is discussed in detail in Section 6 of this report.

9.2 Liquid Waste Collection System

The Radiation Center has two separate waste systems. The sanitary waste system handles all the nonradioactive liquids. The sanitary waste system connects all the washroom fixtures and cold laboratory drains to the campus sewer system. The hot drain system connects all the drains from the radiochemistry laboratories and reactor areas to a retention tank system.

Radioactive effluents from the Center are collected in the retention tank. Before discharge into the sanitary sewer, the contents of the retention tank are pumped to a sampling tank. An aliquot is taken from the tank and evaluated for activity content. The tank's contents are then diluted as necessary to comply with 10 CFR 20 during discharge. All discharges pass through a particulate collection filter.

9.3 Fire Protection System

The fire protection system at the WSU reactor facility consists of three components. The first component is the facility construction that minimizes the use of flammable materials. Concrete, cement blocks, and steel are used extensively in the construction; only minimal amounts of flammable material are used for partitions, doors, office walls, and ceilings. The second component is the number of hand-operated fire extinguishers readily available throughout the facility. These units are designed for use against paper/wood and electrical fires. The third component is the fire detection and alarm system installed throughout the facility. This system employs both smoke and rate-of-temperature-rise detectors and is connected directly to the campus fire alarm center. Key personnel at the campus fire department are familiar with the layout of the Radiation Center and the reactor facility. In addition, the system is provided with several strategically placed manual-pull alarms which annunciate both locally and at the campus fire-alarm center. As an additional safety feature, this component is provided with an indicator panel located in the front entry foyer. This panel indicates the exact location(s) of the detector(s) causing the fire alarm. Although this component is not provided with emergency backup power, it is designed so that if power fails, a "trouble light" provides warning in the campus fire-alarm center.

9.4 Facility Compressed Air System

The compressed air system consists of a compressor, solenoid valves, piping, accumulator, regulator, gauges, and filtration units. The system also is provided with a pressure transducer whose output is routed into the scram logic circuitry. The primary function of the air system is to provide motive force for the pneumatic transfer system and the reactor pulse system (transient rod drive).

9.5 Heating and Ventilating

The Radiation Center contains two independent heating and ventilating systems. One system serves the laboratory areas, exclusive of the reactor, and the other serves the reactor area. A third air-handling system services the fume hoods in the various laboratories. The hoods in all radiochemistry laboratories are exhausted through absolute filters. The radiation confinement function of the ventilation system is discussed in Section 6 of this report.

9.6 Fuel Handling and Storage

Fuel that is not in current use in the reactor core is stored in metal storage racks located on the bottom of the reactor pool. The fuel elements are oriented in the storage racks in the same manner as in the core (that is, lengthwise vertical). The fuel elements are handled by using manually operated tooling designed to facilitate moving the fuel elements while they are totally submerged in pool water, thus minimizing exposure of the operations personnel to radiation.

Unirradiated fuel is stored in a remote location and is protected in a manner consistent with the approved WSU Radiation Center Physical Security Plan.

9.7 Conclusion

The staff concludes that the auxiliary systems at WSU reactor facility are well designed and maintained and the systems are adequate for their intended purposes.

10 EXPERIMENTAL PROGRAMS

The WSU TRIGA reactor serves as a source of ionizing and neutron radiation for research and isotope production. In addition to inpool irradiation capabilities, experimental facilities include a pneumatic transfer system, a thermal column, and several beam ports.

10.1 Experimental Facilities

10.1.1 Pool Irradiations

The open pool of the reactor permits the irradiation of experiments submerged in the vicinity of the core. The decision to perform experiments in the reactor pool--as opposed to using the pneumatic transfer system or a beam tube--is dictated by specimen size and the desired type and intensity of radiation fields. The actual placement of experiments or samples in the core region or the reactor pool is limited by the Technical Specifications.

10.1.2 Pneumatic Transfer Systems

The pneumatic transfer system allows small sealed samples to be rapidly transported between the reactor and the radiochemistry laboratory. The irradiation terminus is in the reflector region adjacent to the core, and the receiver terminus is a shielded box in a ventilated laboratory hood. The exhaust air from this system is released into the monitored reactor area ventilation system. As an additional safety feature, this system is provided with intercepting valves that are remotely operated from the control room. The valves must be placed in the open mode before a sample container can be transported into the reactor. This prevents the unauthorized or inadvertent transport of sample containers into the reactor.

10.1.3 Beam Ports

There are 12 penetrations at various angles and heights through the pool shield wall. These penetrations are normally filled with shielding material; however, the shield material may be removed to provide an external beam of radiation for experimental use when the reactor is positioned in the thermal column end of the pool. These ports also can be used for placing samples near the reactor for irradiation. One beam port is equipped with a shutter and film holder and is used as a neutron radiography facility.

10.2 Experimental Review

Before any new experiment can be conducted using the reactor or experimental facilities, it is reviewed by the WSU Reactor Safeguards Committee. This review and approval process for experiments allows personnel specifically trained in reactor operations to consider and recommend alternative operational conditions--such as different core positions, power levels, and irradiation times--that will minimize personnel exposure and/or the potential release of radioactive materials to the environment.

10.3 Conclusion

The staff concludes that the design of the experimental facilities, combined with the detailed review and administrative procedures applied to all research activities, is adequate to ensure that experiments: (1) are not likely to fail; (2) are unlikely to release significant radioactivity to the environment directly; and (3) 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 facilities do not pose a significant risk of radiation exposure to the public.

11 RADIOACTIVE WASTE MANAGEMENT

The major radioactive waste generated by reactor operations is activated gases, principally ^{41}Ar. A limited volume of radioactive solid waste, primarily resins, is generated by reactor operations, and some additional solid waste is produced by the associated research programs. No radioactive liquid wastes are generated directly by normal reactor operations. The facility does not regenerate the purification system resin bed; thus, very little liquid radwastes are generated. However, a small amount of radioactive liquid waste is developed as a result of several of the Radiation Center research activities.

11.1 ALARA Commitment

The WSU reactor is operated with the philosophy of minimizing the release of radioactive materials to the environment. The university administration instructs all research personnel to develop procedures to limit the generation and subsequent release of radioactive waste materials.

11.2 Waste Generation and Handling Procedures

11.2.1 Solid Waste

Solid waste generated as a result of reactor operations consists primarily of ion exchange resins and filters, potentially contaminated paper and gloves, and occasional small, activated components. Some of the reactor-based research results in the generation of solid low-level radioactive waste in the form of contaminated paper, gloves, and glassware. This solid waste generation has typically contained a few millicuries of radionuclides per year.

The solid waste is collected and held temporarily before being packaged and shipped to an approved disposal site in accordance with applicable regulations.

11.2.2 Liquid Waste

Normal reactor operations produce no radioactive liquid waste. However, many of the research activities conducted within the Radiation Center complex are capable of generating such waste. Liquid waste drains in the reactor room and equipment areas drain into holdup tanks; thus, there is no direct flow into the WSU sanitary sewer system. Other laboratories and experimental areas in the Radiation Center complex, where radioactivity may be found, also are provided with waste lines that flow into these holdup tanks. Thus, all potentially contaminated liquids are collected in the holdup tanks. When the tanks are nearly full, the contents are pumped to a sample tank where the liquid is isolated, mixed, and sampled. The sample is dried, and the residue is analyzed for radioactive content by standard techniques. If the concentrations of radioactive material in the tank are less than the levels specified by 10 CFR 20, the contents are discharged through a particulate filter to the sanitary sewer system. If the concentrations are initially above 10 CFR 20 levels, the contents of the tank are diluted to below those levels before discharge.

The Radiation Center has the capability to solidify small volumes of highly contaminated liquid for shipment offsite as solid waste.

11.2.3 Airborne Waste

The potential airborne waste is comprised of gaseous ^{41}Ar and neutron-activated dust particulates. No fission products escape from the fuel cladding during normal operations. The radioactive airborne waste is produced principally by the neutron irradiation of air and airborne particulate materials in the thermal column and beam ports. This air is constantly swept from the beam room and discharged to the environment through the Radiation Center stack. When it is in the dilution mode, the reactor building exhaust system is equipped with a filter system that collects more than 99.9 percent of the particulate matter. These filters eventually are disposed of as solid potentially radioactive waste.

A stack monitoring system measures the gaseous concentrations in the effluent. During normal operations, no measurable radioactive particulates are released in the air effluents from the Radiation Center stack. WSU has measured the release of ^{41}Ar over the years with gas-sampling instruments calibrated with known quantities of ^{41}Ar. During the years since the reactor was first licensed, WSU has reported an annual release of less than 10 Ci of ^{41}Ar. Both the applicant's and the staff's evaluations show that this amount of release would lead to exposures in unrestricted areas that are well within the limits specified in 10 CFR 20. In accordance with the ALARA principles, WSU has committed itself in its Technical Specifications to several conditions that will minimize ^{41}Ar production and subsequent release.

11.3 Conclusion

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

Because ^{41}Ar is the only potentially significant radionuclide released by the reactor to the environment during normal operations, the staff has reviewed the history, current practice, and future expectations. The staff concludes that the doses in unrestricted areas as a result of actual releases of ^{41}Ar have never exceeded or even approached the limits specified in 10 CFR 20, when averaged over a year. Furthermore, the staff's conservative computations of the dose beyond the limits of the Radiation Center give reasonable assurance that potential doses to the public as a result of ^{41}Ar would not be significant even if there were a major change in the operating schedule of the WSU reactor.

12 RADIATION PROTECTION PROGRAM

WSU has appropriate radiation detection equipment to determine, control, and document occupational radiation exposures at its reactor facility. In addition, the Radiation Center monitors both liquid and airborne effluents at the points of release to comply with applicable regulations. WSU also has developed an environmental monitoring program to verify that radiation exposures in the unrestricted areas around the Radiation Center are well within regulations and guidelines and to confirm the results of calculations and estimates of environmental effects resulting from the WSU research programs.

12.1 ALARA Commitment

The WSU administration has formally established the policy that all operations are to be conducted in a manner to keep all radiation exposures ALARA. All proposed experiments and procedures at the WSU reactor are reviewed for ways to minimize the potential exposures of personnel. All unanticipated or unusual reactor-related exposures are investigated by the operations staff to develop methods to prevent recurrences.

12.2 Health Physics Program

12.2.1 Health Physics Staffing

The routine health physics activities at the WSU reactor are performed by the operations staff. Senior reactor operators are expected to have 4 years of research reactor experience, and reactor operators have at least 2 years of experience.

The Campus Radiation Safety Office is located in the Radiation Center and may be called upon for assistance in the event of an emergency.

12.2.2 Procedures

Detailed written procedures have been prepared for all significant maintenance activities. These procedures address potential radiation considerations and specify anticipated safety requirements.

12.2.3 Instrumentation

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

12.2.4 Training

Nonreactor staff personnel who utilize the reactor are required to pass a certification examination before being permitted to irradiate samples in the WSU reactor.

12.3 Radiation Sources

12.3.1 Reactor

Sources of radiation directly related to reactor operations include radiation from the reactor core, ion exchange columns, filters in the water and air cleanup systems, and radioactive gases, primarily ^{41}Ar and ^{16}N.

The reactor fuel is contained in stainless steel cladding. Radiation exposure from the reactor core is reduced to acceptable levels by water and concrete shielding. The ion exchange resins and filters are routinely changed before high levels of radioactive materials have accumulated, thereby minimizing personnel exposure.

Concentrations of ^{16}N in potentially occupied areas of the reactor room are reduced by using the diffuser in the reactor tank to increase the time required for the gas to reach the surface of the water. This allows the short half-life (7.1 seconds) of the ^{16}N to reduce further the amount of radioactivity released into the reactor room. Personnel exposure to the radiation from chemically inert ^{41}Ar is limited by dilution and prompt removal of this gas from the reactor room and its discharge to the atmosphere where it diffuses further before reaching occupied areas.

12.3.2 Extraneous Sources

Sources of radiation that may be considered as incidental to the normal reactor operation but are associated with reactor use include radioactive isotopes produced for research, activated components of experiments, and activated samples or specimens.

In addition, a 3000 Ci ^{60}Co source is located in the reactor pool, at the end opposite the reactor core. This unit is possessed under authority of the State of Washington (an Agreement State).

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 Fixed-Position Monitors

The reactor facility uses several fixed-position radiation monitors and constant air particulate monitors. These include one radiation monitor and one air particulate monitor on the bridge above the reactor and two radiation monitors in the beam room. All monitors have adjustable alarm set points and read out in the control room.

12.5 Occupational Radiation Exposures

12.5.1 Personnel Monitoring Program

The Radiation Center personnel monitoring program is described in its Radiation Safety Instructions. To summarize the program, personnel exposures are measured by the use of film badges assigned to individuals who might be exposed to radiation. In addition, self-reading pocket dosimeters are available and instrument dose rate and time measurements are used to control individual exposures.

12.5.2 Personnel Exposures

The WSU reactor personnel annual exposure history for the last 5 years is given in Table 12.1. The individuals receiving exposures greater than 0.1 rem in 1981 were not reactor operations personnel, but were experimenters involved with the analyses of a large number of samples.

Table 12.1 Number of individuals in exposure interval

	Number of individuals in each range				
Whole-body exposure range (rems)	1977	1978	1979	1980	1981
No measurable exposure	4	4	6	9	6
Measurable exposure:					
< 0.1	5	7	4	2	10
0.1 to 0.25	0	0	0	0	2
0.25 to 0.5	0	0	0	0	0
0.5 to 0.75	0	0	0	0	2
0.75 to 1	0	0	0	0	0
Number of individuals monitored	9	11	10	11	20

12.6 Effluent Monitoring

12.6.1 Airborne Effluents

As discussed in Section 11, airborne effluents from the reactor facility consist principally of activated gases. The effluent stream is filtered to remove most particulate material, when in the dilution mode, before discharge to the environment through the Radiation Center stack. The filter installation consists of a roughing filter to reduce the loading of the final filters and a high-efficiency particulate air (HEPA) filter that removes more than 99.9 percent of the solid matter in the air stream.

The stack gas monitoring system measures the radioactive gases discharged from the entire Radiation Center complex. The only identifiable radioactive gas is ^{41}Ar. The system consists of a sampling probe positioned near the top of the stack, a sampling pump to maintain a constant flow, a filter to remove particulate contaminants, and a scintillation detector positioned in the middle of a known volume. The instrumentation readout consists of a meter and strip-chart recorder in the control room. The detector count rate is proportional to the amount of radioactive gases in the chamber and hence to the concentration in the air stream. High concentrations and detector failure activate alarms in the control room. This gaseous monitoring system has been calibrated by releasing a small, known quantity of ^{41}Ar into the stack effluent stream.

12.6.2 Liquid Effluent

The reactor generates very limited radioactive liquid waste during routine operations. Small quantities of radioactivity will be produced in the primary coolant system, and experimental activities associated with reactor usage also may generate radioactive liquids. All potentially contaminated liquids are collected in holdup tanks. When the tank is full, the contents are pumped to a sample tank where they are mixed. A sample is analyzed, and liquids with a low concentration of radioactivity are released directly to the sanitary sewer in accordance with 10 CFR 20.303. The liquid effluent line contains a particulate filter to remove all but the smallest particles of solid material. Higher concentrations of liquid waste may be diluted for release or held for radioactive decay, or they may be solidified and handled as solid waste.

12.7 Environmental Monitoring

The WSU has developed a program to monitor radiation exposure above background in the surrounding environment from both reactor operations and the research efforts of the Radiation Center complex.

This consists of about 28 stations that have been established in the unrestricted areas around the reactor facility. Thermoluminescent dosimeters (TLDs) are used to measure the external radiation exposures, which are compared with measurements made within an 80-mi radius of the Radiation Center by the Washington State Department of Social and Health Services.

12.8 Potential Dose Assessments

Natural background radiation levels in the Pullman area result in an exposure of about 85 mrem/yr to each individual residing there. At least an additional 10 percent (approximately 8 mrem/yr) will be received by those living in a brick or masonry structure. Medical diagnosis exposures may add to this natural background radiation level.

Conservative calculations by the staff based on the amount of ^{41}Ar released from the Radiation Center stack predict a maximum annual dose of only a fraction of a millirem in the unrestricted areas. The radiation levels detected by the environmental radiation dosimeters located near the reactor facility have been indistinguishable from the ambient background.

12.9 Conclusion

The staff considers that radiation protection receives appropriate support from the University administration and concludes that the program is acceptably staffed and equipped.

The staff concludes that the effluent and environmental monitoring programs conducted by WSU personnel are adequate to promptly identify significant releases of radioactivity and confirm possible effects on the environment, as well as to predict maximum exposure to individuals in the unrestricted area. These predicted maximum levels are well within applicable regulations and guidelines of 10 CFR 20.

Additionally, the staff concludes that the WSU 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 during the requested renewal period.

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.

13.2 Training

Most of the training of reactor operators is done by inhouse personnel. The licensee's Operator Requalification Program has been reviewed, and the staff concludes that it meets applicable regulations (10 CFR 50.34(b).

13.3 Emergency Planning

10 CFR 50.54 and Appendix E to 10 CFR 50 require that nonpower reactor applicants/licensees develop and submit emergency plans. The applicant submitted a plan that was developed following the recommended guidance in Regulatory Guide 2.6 (1979, For Comment issue) and guidance in ANS 15.16 (1978 Draft). However, both of these guides have been revised. (Revision 1 to Regulatory Guide 2.6 was issued for comment in March 1982; Draft 2 of ANS 15.16 was issued November 1981.) The applicant has until November 3, 1982 to revise the WSU emergency plan as necessary and submit it for staff review and approval.

13.4 Operational Review and Audits

In addition to the line personnel for reactor operations and the radiation safety personnel, a Reactor Safeguards Committee, reporting to the Dean of the Graduate School, reviews and oversees the facility operations. This committee consists of one individual from the reactor operations staff and qualified people from the WSU facility and faculty who are experts in radiological and reactor technologies. Another committee, the Radiation Safety Committee, is responsible for reviewing the other major radiation facilities and radioisotope utilization at WSU and is not primarily involved with the reactor. The Reactor Safeguards Committee must review and approve plans for modifications to the reactor, new experiments, and proposed changes to the license or to procedures. This committee also is responsible for (1) arranging and conducting review audits of reactor facility operations and management and (2) for reporting the results of these audits to the Dean of the Graduate School.

13.5 Physical Security Plan

WSU has established and maintained a program designed to protect the reactor and its fuel and to ensure its security. The NRC staff has reviewed the plan and visited the WSU site. The staff concludes that the plan, as amended, meets the requirements of 10 CFR 73.67 for special nuclear materials of moderate strategic significance. WSU's licensed authorization for reactor fuel falls within that category. Both the Physical Security Plan and the staff's evaluation are withheld from public disclosure under 10 CFR 2.790(d)(1) and 10 CFR

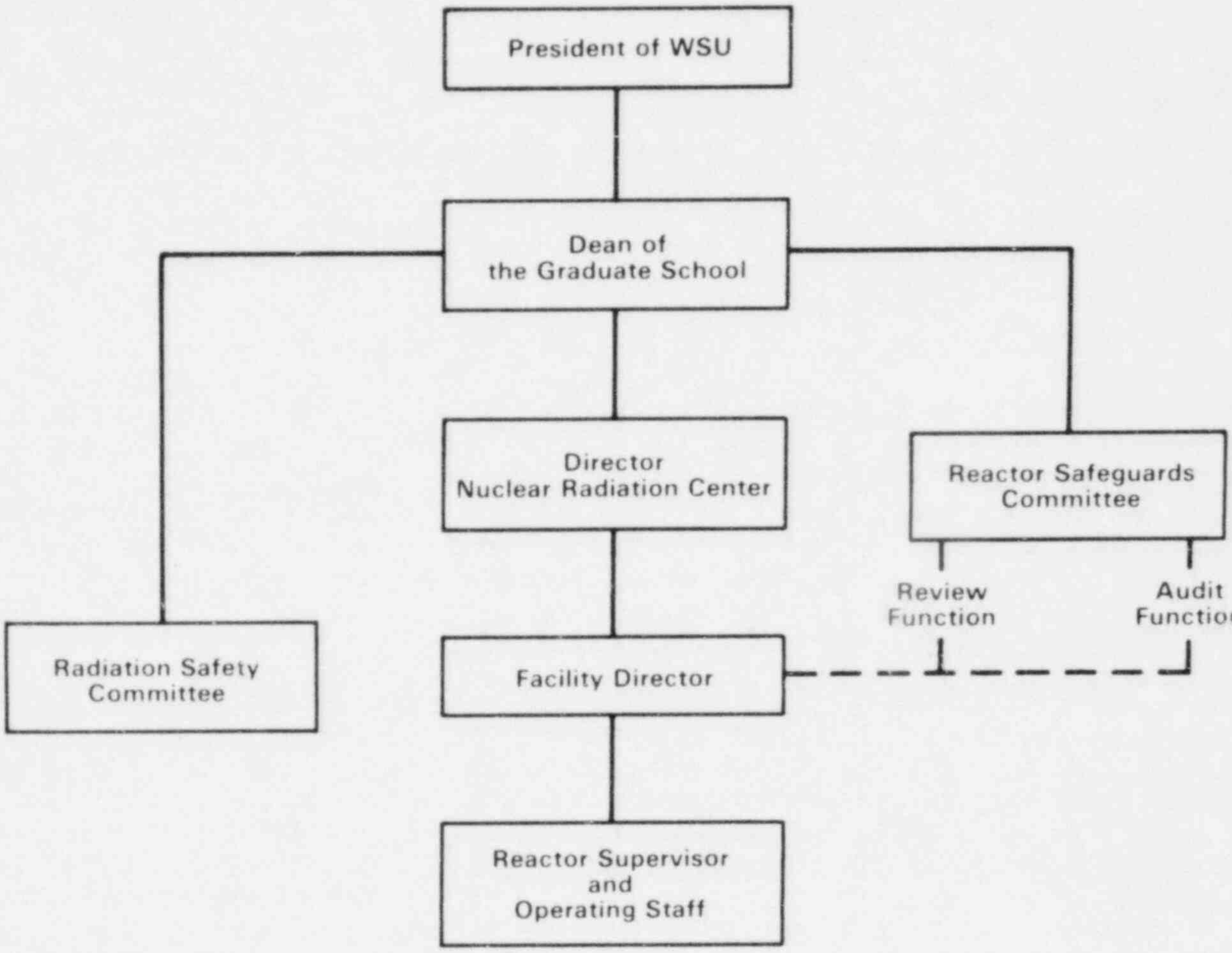


Figure 13.1 Facility Organization

9.5(a)(4). Amendment 9 to facility license R-76 dated July 2, 1979, incorporated the Physical Security Plan as a condition of the license.

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

14 ACCIDENT ANALYSIS

As part of its evaluation of several pending license renewals for nonpower reactors, the staff asked one scientific laboratory to analyze generic reactor accidents for U-ZrH_x fueled reactors (NUREG/CR-2387) and a second scientific laboratory to evaluate the applicant's submitted documentation (private communication from LANL). These analyses included the likelihood of various types of accidents and the potential consequences to the public.

Among the potential accidents considered to be credible, the one with the greatest effect on the environment and the unrestricted area outside of the WSU Radiation Center is the loss of cladding integrity of an irradiated fuel rod in air in the reactor room. This has been designated as the design-basis accident and, for purposes of classification, the staff will refer to it as the "fuel-handling accident." In more detail below, the staff has evaluated other possible accident sequences that originate in the intact reactor core. None of these pose a significant risk of cladding failure. However, it is possible that an operator, while removing a fuel element from the core or relocating one previously removed following irradiation, could experience an accident that would breach the integrity of the fuel cladding. If this cladding were ruptured, then noble gases and halogen fission products could escape into the pool.

This will be designated as the design-basis accident (DBA) for a TRIGA reactor. A DBA is defined as a postulated accident with potential consequences greater than those from any event that can be mechanistically postulated. Thus, the staff assumes that the accident occurs but does not attempt to describe or evaluate deterministically the mechanical details of the accident or the probability of its occurrence. Only the consequences are considered.

The following potential accidents or effects were considered for evaluation and analysis.

(1) rapid insertion of reactivity (nuclear excursion)
(2) loss of coolant
(3) metal-water reactions
(4) misplaced experiments
(5) mechanical rearrangement of the fuel
(6) effects of fuel aging
(7) handling of irradiated fuel

14.1 Rapid Insertion of Reactivity

This potential event is one in which the maximum excess reactivity available in a single credible event is inserted into the reactor instantaneously.

The theory of the neutronic behavior of the U-ZrH_x fuel and all experimental measurements have shown that this fuel exhibits a strong, prompt, negative temperature coefficient of reactivity. This coefficient derives from the bonding of the hydrogen to the zirconium, and as long as bonding exists, a nuclear excursion is terminated in a self-limiting transient. Various investigators have determined that at temperatures above approximately 1100°C some local breaking of the bond and consequent dehydriding may occur (Simnad and Dee, 1968; Kessler et al., 1966; GA-6874, 1966). However, if most of the fuel volume is below this temperature, not only does the temperature coefficient terminate a nuclear excursion, it also causes a loss of reactivity as the steady-state temperature of the fuel is raised. Experimental demonstrations of these results have been verified at many operating reactors using U-ZrHx fuel (GA-4314, 1980). Because of the action of the inherent temperature coefficient, temporary loss of positive reactivity will result from both steady-state and pulsing operations.

However, it is theoretically possible to add enough excess reactivity rapidly to cause an excursion that would not be thermally terminated before fuel damage occurred (Buttrey, 1965).

Therefore, the staff has considered scenarios in which the reactor is assumed to be operating at power levels between 0 and 1 MW, and the maximum amount of excess reactivity credibly available is added rapidly to the core. The applicant has assumed the inadvertent insertion of 3.75$ (2.63 percent $\Delta k/k$) of excess reactivity, which corresponds (1) to the effectiveness of a FLIP fuel cluster in the most reactive locations and (2) to the effectiveness of the transient rod fully withdrawn.

The staff concurs that these are the two potential events at WSU leading to maximum fuel temperatures, and maximum stresses in fuel cladding. To simplify if the analysis, the applicant postulated that the reactivity insertions were made instantaneously. Under this assumption, the transient produces the maximum integrated energy; hence produces the maximum temperature increase. Therefore, the maximum ultimate fuel temperature that will result in the transient is initiated at the full steady-state power of 1 MW.

On the other hand, if the same amount of excess reactivity were inadvertently inserted in a realistic or physically possible way, the integrated energy produced will be less than that computed as outlined above.

Thus, the lower the fuel temperature from which the transient is initiated, the higher the ultimate fuel temperature will be. Therefore, the staff agrees that the applicant's analysis describes a hypothetical condition worse than any credible one. Furthermore, the manipulation of fuel and cocking of the transient rod during full-power steady-state operation are not authorized by the facility Technical Specifications so both of the initiating events are very unlikely to occur.

The staff agrees that under these hypothetical operating conditions, the maximum fuel temperatures computed by the applicant could occur as a result of these postulated transients, namely 1140°C. The staff does not agree, however, that the accuracy of this value and the so-called safety limit of 1150°C justify concluding that these two temperatures are significantly different. On the other hand, this maximum temperature would be reached by a very small fraction of the fuel in the hottest rod, so the average temperature and, hence, the hydrogen pressure would be well below the limit for clad rupture. To operate the reactor in steady-state mode and to support a transient nuclear excursion, the moderating and reflecting water is necessary. Therefore, the fuel would be totally immersed in water, the cladding would be cooled continuously, and its temperature would remain well below the highest fuel temperature. In many pulses performed in U-ZrH_x fuel, General Atomic has observed no fuel damage in rods pulsed to comparable temperatures (GA-9350, 1969).

Additionally, data giving the fuel temperature history following a large pulse (transient) demonstrate that natural convective water cooling of the fuel lowers its temperature several hundred degrees within 2 minutes of the transient (GA-5400, 1965). Hence, if the ambient cooling water is present at least that long after the pulse, most of the pulse energy will have been transferred from the fuel to the water.

From the above considerations, the staff concludes that there is no credible nuclear excursion possible with the WSU reactor that could lead to fuel-melting or cladding failure resulting from high temperature or high internal gas pressure. Therefore, there is reasonable assurance that fission product radioactivity will not be released from the fuel to the environment as a result of a reactor pulse or excess reactivity transient.

14.2 Loss of Coolant

A potential accident that would result in increases in temperatures of the fuel and cladding is the loss of coolant shortly after the reactor has been operating. Because the water is required for adequate neutron moderation, its removal would terminate any significant neutron chain reaction. However, the residual radioactivity would continue to deposit heat energy in the fuel. It is assumed that sufficient water is lost to uncover the core and that subsequent heat removal from the fuel is provided only by air convection. Several investigations have evaluated such scenarios under various assumptions (Simnad, Foushee, and West, 1976; GA-5400, 1965; GA-6596, 1970). In the WSU reactor, the core will be completely immersed in water as long as the level of the water is at least 6½ ft above the tank bottom. That would require about 15,000 gal of water in the tank. Therefore, about 47,000 gal could be removed before the core is uncovered. If it is assumed that a gross constant leak of 1500 gal/min occurs, the core would remain covered for at least 30 minutes. If convective water cooling continued that long, for a core that had been operating at 1 MW long enough to achieve fission product equilibrium (to be conservative), the peak temperature that the fuel would reach would be less than 950°C. This maximum temperature would not be reached in less than about 2 hours. Not only would this maximum temperature not lead to rupture of the fuel cladding, but the time scale for the entire event would allow for remedial action.

Section 14.1 addresses the dependence of pulse size and the ultimate maximum fuel temperature on the temperature at which the transient is initiated. Accordingly, it would be physically impossible at the WSU reactor to produce a large pulse at the end of an extended operation at 1 MW steady state unless the fuel temperature was first lowered to approximately that of the ambient water. Then, for the transient to contribute substantially to the fuel heat content after the loss of coolant, the transient would necessarily have to occur within about 2 minutes of the time that the core becomes uncovered.

If all water were lost from the region of the core, the reactor would become subcritical and the production of additional fissions would cease; therefore, only the heat resulting from fission product beta and gamma rays need be considered.

If the reactor were pulsed shortly after an extended run, the heating resulting from the additional inventory of fission products would be neglible. Furthermore, as indicated in Section 14.1, the fuel temperature must necessarily be reduced to water ambient temperature before a pulse of any significant size could occur. Therefore, sufficient water would still be present to provide cooling following the pulse. Accordingly, the staff concludes that a relatively rapid loss of coolant from the reactor tank following extended operation at 1 MW would not result in fuel or clad melting or loss of cladding integrity.

14.3 Metal-Water Reactions

Chemical reactions, especially oxidation, may occur if sufficiently hot metal is brought into contact with water. This has been an area of concern and study in designing reactors since the early 1950s. Therefore, there is an extensive body of literature on the subject (Baker and Just, 1962; Baker and Liimatakinen, 1973; Buttrey et al., 1965). From the laboratory tests, it is concluded that the metal (reactor fuel or cladding) would have to be heated to very high temperatures (for example, above the melting point) and/or be fragmented into small hot particles and injected into water to support a rapid (explosive) chemical reaction. Either of these conditions implies a prior catastrophic event of some sort, which presumably would have to originate with a nuclear excursion or loss of coolant. In Sections 14.1 and 14.2 these events were shown not to be credible in a 1-MW U-ZrH_x fueled reactor like the one authorized for operation at WSU.

Additionally, some of the studies (Baker and Liimatakinen, 1973) include metal-air and metal-steam chemical reactions. Violent (explosive) reactions do not appear to be possible in air or steam at atmospheric pressure, even though rapid reactions may occur at sufficiently high temperatures with specially prepared samples and conditions.

In addition to the investigations referenced above, General Atomics has experimentally plunged heated samples of unclad ZrH_x into water to examine possible conditions for initiating and sustaining a metal-water reaction (Lindgren and Simnad, 1979). Up to temperatures of about 1200°C, there was no chemical reaction of the metal except for the formation of a relatively inert oxide film. Furthermore, most of the hydrogen may have been driven off in the hottest unclad test samples, so the metal surface in contact with the water would have been mostly zirconium.

Based on the above considerations, the staff concludes that there is reasonable assurance that rapid (violent) metal-water, metal-air, or metal-steam reactions will not occur in a TRIGA-type reactor, operating at 1 MW or below, with maximum available excess reactivity as authorized at the WSU reactor.

14.4 Misplaced Experiments

This type of potential accident is one in which an experimental sample or device is inadvertently located in an experimental facility where the irradiation conditions could exceed the design specifications. In this case, the sample might become overheated or develop pressures that could cause a failure of the experiment container. As discussed in Section 10, all new experiments to be conducted at the WSU reactor are reviewed before insertion, and all experiments in the region of the core are separated from the fuel cladding by at least one barrier such as the pneumatic transfer tube, the wet tube, or the core grid box.

The staff concludes that the experimental facilities and the procedures for experiment review at the WSU are adequate to provide reasonable assurance that failure of experiments is not likely, and, even if failure occurred, breaching of the reactor fuel cladding will not occur. Furthermore, if an experiment should fail and release radioactivity within an experimental facility, there is reasonable assurance that the amount of radioactivity released to the environment would not be more than that from the accident discussed in Section 14.7.

14.5 Mechanical Rearrangement of the Fuel

This type of potential accident would involve the failure of some reactor system, such as the support structure, or could involve an externally orginated event that disperses the fuel and, in so doing, breaches the cladding of one or more fuel rods. The staff has not developed detailed scenarios for accidents such as these. Section 14.7 discusses a scenario assuming the failure of the cladding of an element after extended reactor operation and evaluates possible doses resulting from various hypothetical scenarios for release of the inventory of radioactivity. This approach should address the spectrum of fuel clad failures. (The scenario in which the initiating event causes a rearrangement of the fuel in such a way that all of the control rods are somehow simultaneously ejected from the core and a nuclear excursion results is discussed in Section 14.1.)

The staff concludes that no mechanical rearrangement that is credible would lead to an accident with more severe consequences than those accidents considered in Sections 14.1 and 14.7.

14.6 Effects of Fuel Aging

The staff has included this process in this section so that all credible effects are addressed. However, as discussed in more detail in Section 17, fuel aging should be considered normal with the continued use of the reactor and it is expected to occur gradually. The reactions external to the cladding that might occur also are addressed in Section 17. This section addresses the possibility of internal reactions.

There is some evidence that the $U\text{-}ZrH_x$ fuel tends to fragment with use, probably because of the stresses caused by high temperature gradients and the high rate of heating during pulsing (GA-A16613, 1981; GA-4314, 1980). Some of the possible consequences of fragmentation are (1) decrease in thermal conductivity across cracks, leading to higher central fuel temperatures during steady-state operation (temperature distributions during pulsing would not be affected significantly by changes in conductivity because pulsing is completed before significant heat redistribution by conduction occurs) and (2) fragmentation would allow more fission products to be released into the cracks in the fuel. However, it is not expected that this increase would be large when the two mechanisms for release are considered. At temperatures above about 400°C, diffusion of the noble gases accounts for a large fraction of the release to the gap. The fragmentation of the fuel would allow diffusion to the nearest surface to occur more rapidly, but there is no apparent reason to expect a larger ultimate release. The other mechanism, low-temperature emission from a surface layer into a crack, might increase because of more "gaps," but the principal gap between clad and fuel almost certainly must become smaller if the fuel body fragments and expands. Furthermore, the cracks would not separate very far, so most fission products would impinge onto the opposite surface and then have to diffuse back out to be released into the gaps.

The staff concludes that the two likely processes of aging of the U-ZrH_x would not have a significant effect on the operating temperature of the fuel or on the accumulation of gaseous fission products within the cladding. Therefore, the staff also concludes that there is reasonable assurance that fuel aging will not significantly increase the likelihood of fuel-cladding failure, or the quantity of gaseous fission products available for release in the event of loss of cladding integrity.

14.7 Handling Irradiated Fuel

This potential accident includes various incidents that may occur to one or more of the fuel elements removed from the reactor core in which the fuel cladding might be breached or ruptured. The staff allowed the scenario to include the range from the time immediately after a long run at full licensed power to any longer time needed, for example, to move stored irradiated fuel from a rack in the pool into the reactor room. The staff did not try to develop a detailed scenario; it simply assumed that the cladding of one fuel rod certainly fails and that all of the fission products accumulated in the gap are released abruptly.

Several series of experiments at General Atomics have obtained data on the species and fractions of fission products released from U-ZrH_x under various conditions (Baldwin, Foushee, and Greenwood, 1980; Foushee and Peters, 1971; Simnad, Foushee, and West, 1976). The noble gases were the principal species found to be released, and, when the fuel specimen was irradiated at temperatures below about 350°C, the fraction released could be summarized as a constant equal to 1.5×10^{-5}. The species released did not appear to depend on the temperature of irradiation, but the fraction released increased significantly at much higher temperatures.

General Atomics has proposed a theory describing the release mechanisms in the two temperature regimes that appears to be plausible, although the data do not agree in detail. It seems reasonable to accept the intepretation of the low-temperature results, which implies that the fraction released for a typical TRIGA fuel rod will be (1) a constant, (2) independent of operating history or details of operating temperatures, and (3) apply to fuel whose temperature is not raised above approximately 400°C for any appreciable time. This means that the 1.5 x 10^{-5} could be reasonably applied to TRIGA reactors operating up to at least 800 kW of steady state.

The theory in the fuel temperature regime above approximately 400°C is not as well established. The proposed theory of release of the fission products incorporates a diffusion process that is a function of temperature and time. Therefore, in principle, details of the operating history and temperature distributions in fuel rods would be required to obtain actual values for release fractions at the higher temperatures.

Because the validity of the theory may not justify this detail and because any prediction of future operating schedules of most research reactors is not justified, the applicant selected a release fraction of 1.2 x 10^{-4}, which, according to the General Atomics results, corresponds to the 500°C authorized, maximum measured operating fuel temperature for the WSU reactor. Because the General Atomics measurements have been adjusted to infinite operating times at the various temperatures, it is likely that this approach will give a conservatively high value compared with the maximum possible release at the WSU reactor. During steady-state operation at 1 MW, the WSU reactor's measured fuel temperature does not exceed 500°C, and, because the thermocouples are near the axial center of the hottest fuel rods, they measure the region of maximum temperature, which is well above the core average.

Because the noble gases do not condense or combine chemically, it is correct to assume that any released from the cladding will diffuse in the air until their radioactive decay. On the other hand, iodines are chemically active and are not volatile below about 180°C. Therefore, some of the radioiodines will be trapped by materials with which they come in contact, such as water and structures. In fact, evidence indicates that most of these iodines will either not become or not remain airborne under many accident scenarios applicable to nonpower reactors (NUREG-0771). However, to be certain that the fuel-clad-failure scenarios discussed below led to upper limit dose estimates for all events, the staff as well as the applicant assumed that 100 percent of the iodines in the gap become airborne. This assumption will lead to computed thyroid doses that may be at least a factor of 100 too high in some scenarios. The staff has reviewed the various acceptable methods for computing the potential dose beyond the confines of the WSU reactor room in case of a fission-product release. The methods outlined in various Regulatory Guides such as 1.3, 1.145, 1.109, 3.34, and 3.35, give results that are conservative for nonpower reactors.

In fact, for the quantity of radioactivity that could result from the failure of the cladding of one maximally irradiated WSU fuel rod, these methods generally give results which are extremely conservative. Three accident scenarios are evaluated below. The staff agrees with the applicant that those adequately encompass the range of credible fuel-clad failure events, and finds the applicant's results generally acceptable. However, for the second and third scenarios, the staff has used a somewhat different approach, and, therefore, obtained potential dose values different from the applicant's. These results also are discussed below. The source strengths and resulting doses are summarized in Table 14.1.

Table 14.1 Activity and dose equivalents from postulated fuel-handling accidents

Nuclides	Curies Released[a]	Dose equivalent (mrem)		
		Scenario 1	Scenario 2	Scenario 3
Iodines	1.0	not applicable[c]	< 140[b]	< 10[b]
Kryptons	0.38	13[c]	< 1.6	< 6 x 10^{-3}
Xenons	0.78	27[c]	< 3.4	< 1.4 x 10^{-2}

[a]Assumes: no decay from equilibrium 1.2 x 10^{-4} = release fraction, a single fuel rods generating 30 kw, (thermal) reactor core cperating at 1 MW steadstate

[b]Thyroid dose committment

[c]Initial dose rate, mrem/hr

(1) In a single fuel-rod-clad failure in air immediately after an extended 1-MW run, the applicant assumes that the reactor room exhaust dampers close and that all of the noble gas and iodine radionuclides in the fuel-cladding gap are released from the cladding and form a uniform distribution in the reactor room air instantly. Furthermore, all of the radioactivity is confined in the room. The initial whole-body (immersion) dose rate to a person in the middle of the reactor room would be approximately 40 mrem per hour. This initial dose rate is an upper limit, because of the conservative assumptions. Because there is no credible way in which this type of accident could occur without the person in the room being alerted immediately, orderly evacuation of the room within minutes would be accomplished. There would be no airborne radioactivity in unrestricted areas outside of the building in this scenario.

(2) In this scenario, both the staff and the applicant assumed the same event occurred as in scenario (1), but that all of the air in the reactor room containing the fission products subsequently escaped from the building at a uniform rate. (For example, the escape might be out of the building exhaust stack.) However, the staff assumed that the escape occurred with no decrease in source strength as a result of radioactive decay, whereas the applicant included the realistic decay properties of the airborne fission products. On the other hand, the applicant assumed that the exhausted air mass could be treated as a large hemispherical cloud of uniformly diluted fission products, but the staff treated a more realistic finite plume. As a result of these different assumptions, the staff and the applicant have computed potential doses that are different, but in both cases these doses are conservatively much higher than could realistically occur.

Under the staff's assumptions, the whole-body dose to a person just outside of the building for the entire leakage time would be less than 5 mrem, and the committed dose to the thyroid from breathing iodines in the air would be less than 140 mrem. In this scenario, as in scenario (1), these doses would be upper limits either because the exposed subject could be warned and evacuated, or the escape of air could be controlled, because it can be assumed that operations personnel would be on hand and alerted.

(3) The third accident event analyzed is the same as accident (2) but considers the potential exposures to personnel beyond the control of the WSU authorities.

The nearest residences of the public are about 400 m from the Radiation Center. However, to add to the conservatism, the staff computed potential dose to a person at 200 m, assuming that 100 percent of the iodines and noble gases released from the fuel cladding escape from the building and are carried by a $1\text{-}ms^{-1}$ wind, with Pasquill Type F atmospheric conditions. This wind speed and stability condition are very infrequent at WSU, so these assumptions lead to a "worst case" analysis. Consistent with the assumption of a finite plume used in scenario (2) the staff compared evaluation of scenario (3) with a recent publication on this subject (G.P. Lahti, et al, 1981) and found it acceptable. Thus, at 200 m from the WSU reactor building, the staff computed a total body immersion dose of less than 0.02 mrem and a thyroid dose of approximately 10 mrem. As noted above, both of these computations are based on conservative assumptions about the source strengths and the atmospheric dispersion conditions, so the results are higher than could realistically occur.

In accordance with the discussions and analyses above, the staff concludes that if one fuel rod from the WSU reactor were to release all noble gaseous and iodine fission products accumulated in the fuel-cladding gap, radiation doses to both occupational personnel and to the public in unrestricted areas would be well within the limits stipulated in 10 CFR 20. This conclusion is valid even for the very unlikely accident scenario selected, namely that the clad failure occurs immediately after an extended steady-state operation and that all of the gaseous radioactivity in the gap, including all iodines, escapes and is carried downwind. These assumptions correspond to a very conservative scenario.

Furthermore, from the results the staff obtained, even if one-half of the fuel rods failed simultaneously, the expected whole-body doses in unrestricted areas beyond 200 m would be less than 5 mrem and still fall within 10 CFR 20 limits.

The staff assumed in scenarios (2) and (3) that the fail-safe engineered safety feature (the exhaust system dampers) did not function. This adds to the conservative nature of the scenarios. Therefore, the staff concludes that even in the event of a multiple fuel clad failure at the WSU reactor, there would be no significant risk to the health and safety of the public.

14.8 Conclusion

In accordance with the information, references, and analyses in this section, the staff concludes that the credible possible accidents involving the WSU reactor do not pose significant hazards to the public or to the environment.

15 TECHNICAL SPECIFICATIONS

The applicant's Technical Specifications evaluated in this licensing action define certain features, characteristics, and conditions governing the continued operation of this facility. These Technical Specifications are explicitly included in the renewal license as Appendix A. Formats and contents acceptable to the NRC have been used in the development of these Technical Specifications, and the staff has reviewed them using the Draft Standard ANS 15.1 (September 1981) as a guide.

Based on its review, the staff concludes that normal plant 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 offnormal or accident events.

16 FINANCIAL QUALIFICATIONS

The WSU reactor is owned and operated by a state university in support of its role in education and research. Therefore, the staff concludes that funds will be made available, as necessary, to support continued operations and eventually to shut down the facility and maintain it in a condition that would constitute no risk to the public. The applicant's financial status was reviewed and found to be acceptable in accordance with the requirements of 10 CFR 50.33(f).

17 OTHER LICENSE CONDITIONS

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 offnormal or accident event could cause some significant exposure. Even a design-basis accident (defined as one 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 operation will cause significant degradation in these features. Furthermore, because loss of integrity of fuel cladding is the design-basis accident, the staff must consider mechanisms which 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, in the order in which they were identified above, are

(1) Some of the standard TRIGA fuel in the core has been in use since 1967 and has been subjected to a maximum of 15 percent burnup of ^{235}U. Some TRIGA fuel at more extensively used reactors has been in use for at least four times as much burnup, with no observable degradation of cladding as a result of radiation. The newer FLIP fuel has been subject to burnups of up to 3 percent. It is unlikely that the WSU program will change during the renewal period and alter this conclusion.

(2) The possibility of approaching such pressures would occur if the entire fuel element including the cladding were to be heated to more than 930°C, (GA-4314 and Simerad, Foushee, and West, 1976). Although it is likely that some points in the fuel would approach this temperature for a few seconds following a 2.50$ (1.75 percent $\Delta k/k$) pulse, only a simultaneous and instantaneous total loss of coolant could cause the cladding temperature to exceed a few hundred degrees. Because the staff considers that there is no credible scenario involving all of these assumptions, the staff concludes that there is no realistic event that would cause the elastic limit of the cladding to be exceeded.

(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 conductivity below about 5 μmho-cm^{-1}, corrosion of the stainless steel cladding is expected to be negligible, even over a total 40-year period.

(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 which are placed near the core are isolated from the fuel cladding by a water gap and at least one metal barrier, such as the pneumatic tubes or the core experiment tube. Therefore, the staff concludes that loss of integrity of cladding through damage does not constitute a significant risk to the public.

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

The second aspect of risk to the public involves the consequences of an accident. Because the WSU reactor has not and is not expected to operate on the maximum available schedule, the inventory of radioactive fission products will be far below that postulated in the evaluation of the design-basis accident both by the applicant and the NRC staff (see Section 14). Therefore, the staff concludes (1) that the risk of radiation exposure to the public has been acceptable and well within all applicable regulations and guildelines during the history of the reactor, and (2) that there is reasonable assurance that there will be no increase in that risk in any discernible way during this renewal period.

17.2 Multiple or Sequential Failures of Safety Components

Of the many accident scenarios hypothesized for the WSU TRIGA reactor, none produce consequences more severe than the design-basis accidents reviewed and evaluated in Section 14. 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 included a mechanism by which the failure of integrity of one fuel element can cause or lead to the failure of additional elements. Therefore, if more than one cladding 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 one control rod 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.

18 CONCLUSIONS

Based on its evaluation of the application as set forth above, the staff has determined that

(1) The application for renewal of Operating License R-76 for its research reactor filed by the Washington State University, dated May 15, 1979, as amended, complies with the requirements of the Atomic Energy Act of 1954, as amended (the Act), and the Commission's regulations set forth in 10 CFR, Chapter 1.

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

(3) There is reasonable assurance (a) that the activities authorized by the operating license can be conducted without endangering the health and safety of the public; and (b) that such activities will be conducted in compliance with the regulations of the Commission set forth in 10 CFR, Chapter 1.

(4) The applicant is technically and financially qualified to engage in the activities authorized by the license in accordance with the regulations of the Commission set forth in 10 CFR Chapter 1.

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

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16. ABSTRACT (200 words or less)

This Safety Evaluation Report for the application filed by the Washington State University (WSU) for a renewal of operating license number R-76 to continue to operate a research reactor has been prepared by the Office of Nuclear Reactor Regulation of the U. S. Nuclear Regulatory Commission. The facility is owned and operated by the Washington State University and is located on the WSU campus in Pullman, Whitman County, Washington. The staff concludes that the TRIGA reactor facility can continue to be operated by WSU without endangering the health and safety of the public.

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