Washington State University
Nuclear Radiation Center
Pullman, WA 99164-1300
509-335-8641
FAX 509-335-4433

September 22, 1995

Marvin Mendonca
Sr. Project Manager
U.S. Nuclear Regulatory Commission
Office of Non-Power Reactors
MS 0-11-B-20
Washington, DC 20666

Dear Mr. Mendonca:

In light of the pending establishment of a Medical Therapy Beam for Human Therapy at Washington State University and the fact that the facility's license will expire in 2002, the facility is considering requesting a 10 year license extension. It simply is not practical to spend all the funds and make the necessary licensing changes for such a therapy facility with only a 4 or 5 year useful life.

Attached are draft documents related to the proposed facility license extension. After you have reviewed these materials, please contact the facility to let Dr. Tripard know that you are ready to discuss the documents with me. I will then contact you by telephone to discuss what needs to be done in the way of modification to these documents and the meeting of any additional requirements.

Sincerely,

W. E. Wilson

W.E. Wilson
Consultant

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APPLICATION FOR TEN YEAR LICENSE EXTENSION FOR FACILITY LICENSE NO. R-76 FOR THE WASHINGTON STATE UNIVERSITY MODIFIED TRIGA NUCLEAR REACTOR

1. GENERAL INFORMATION (10 CFR 50.33)

(a) Name of Applicant

Washington State University
Nuclear Radiation Center

(b) Address of Applicant

Washington State University
Pullman, Washington 99164

(c) Business of Applicant and Officers

(1) Business - Educational Institution (Land Grant College)

(2) Officers

a. University

i. President of WSU - Samuel H. Smith

ii. Provost and Academic Vice President - Thomas George

iii. Vice Provost for Research and Dean of the Graduate School - Robert V. Smith

b. Nuclear Radiation Center

i. Director, Nuclear Radiation Center - Gerald E. Tripard

ii. Reactor Supervisor, Nuclear Radiation Center - Jerry Neidiger

(d) The applicant is an Educational Institution which is a Land Grant University in the State of Washington under the control of the Laws of the State of Washington.

(e) Class of License

Class 104 Production and Utilization Facility, Facility License No. R-76

(f) Financial Considerations

(1) Budget Information

a. Washington State University is a land grant educational institution in the State of Washington funded directly by State appropriations approved by the Legislature of the State. Funding is appropriated to

the University on a biannual basis and amounted to $152,766,672.00 for the current biennium. The most recent financial report of WSU is attached.

b. The current annual budget for the Nuclear Radiation Center in which the Facility is located is $254,6331.50 as shown in the attached budget statements. The Nuclear Radiation Center budget covers a variety of activities including the TRIGA reactor facility.

(2) Operating Costs

The cost of operating the WSU TRIGA reactor facility and attendant research projects during the current year is $180,000. The funds come from Program 10D of the university budget entitled "Other Organized Research." Since all funding for WSU is by action of the State Legislature, it is not possible to guarantee funding for any program within the university. However, the State of Washington is an Agreement-State and has in the past chosen to comply with all Federal regulations and commitments along with the costs thereof. It is thus deemed that it would be incumbent upon the State to continue to provide the necessary funding for operation of the facility.

(3) Decommissioning Costs

In 1989 the Nuclear Division of Westinghouse Electric Corporation made a detailed technical and cost proposal for the decommissioning of the WSU Modified TRIGA Reactor. The 1994 inflation adjusted decommissioning costs are estimated to be $4,312,000. If the facility is shut down by action of the university or termination of the facility license, the funds required to decommission the facility would be provided by appropriate sources within the university and the State of Washington.

2. <u>FILING OF APPLICATION</u> (10 CFR 50.30)

(a) Two notarized signed copies of the letter of application for the extension of Facility License R-76 are herewith submitted in accordance with Paragraph (b) of 10 CFR 50.30.

(b) Ten copies of the application information constituting this document including the information required by 50.33 are hereby submitted.

(c) The SAR of May, 1979 as amended is still valid for the facility and thus no new SAR need be submitted, except for the impact of the recent changes to 10 CFR 20 on the Design Basis Accident.

(d) The applicant hereby claims to be exempt from the Filing Fees specified by 50.30 (3) under the provisions of 170.11 (1.4).

(e) Ten copies of the applicant's "Environmental Impact Appraisal" is hereby submitted to fulfill the requirements of 50.30 (f).

3. TECHNICAL INFORMATION (10 CFR 50.34)

(a) The Safety Analysis Report of May, 1979 as amended is still valid for the facility and thus a complete new SAR need not be submitted. Attached is a Revised Design Basis Accident Analysis using modern methodology and the new requirments of 10 CFR 20.

(b) The Emergency Plan of September, 1963 as amended is still valid for the facility and a new plan need not be submitted.

(c) The existing Technical Specifications for the facility are still valid and thus a new set need not be submitted.

(d) Requalification Program (10 CFR 55)

The current existing "Operator Requalification Program for the Washington State University TRIGA Facility" of March 22, 1989 meets the current requirements and thus a new program need not be submitted.

(e) Physical Security Plan (10 CFR 50.34[c])

The current existing "Physical Security Plan for the Washington State University Nuclear Radiation Center" approved September 12, 1984 meets the current standards and is still valid for the facility. Thus, a new plan need not be submitted.

(f) SNM Information (10 CFR 73.47)

The SNM requirements for the facility in the existing license as listed in Table I below are quite adequate and need not be changed.

TABLE I
SNM REQUIREMENTS FOR WSU TRIGA REACTOR FACILITY

Maximum U-235	Maximum Pu	% Enrichment	Exempt Status*
10.0 kg		<20	Exempt 10 CFR 73.6(a)
15.0 kg		>20	Exempt 10 CFR 73.6(b)
4.90 kg		>20	Not Exempt
	32 grams		Exempt 10 CFR 73.6(c)

*Material is exempt provided that it meets the requirements for exemption pursuant to the cited provisions of 10 CFR 73.

WASHINGTON STATE UNIVERSITY	BUDGET STATEMENT BUDGET TITLE	BUDGET	DATES INCLUDED FROM	TO	PAGE
	NUCLEAR RADIATION CENTER	3960	07-01-95	08-31-95	1

PROGRAM 10D PROJECT 0001 OPERATIONS 17% OF FISCAL YR. ELAPSED

(1) PROJECT SUMMARY TO DATE BY OBJECT	PROJECT BUDGET	EXPENDED TO DATE	OUTSTANDING ENCUMBRANCES	BALANCE	PCT. USED
01 WAGES	3,000.00	7,693.19		4,693.19-	256
02 PERSONAL SERVICE CONTRACTS	.00	1,100.00		1,100.00-	--
03 GOODS AND SERVICES	54,199.00	7,736.04	757.87	45,705.09	16
04 TRAVEL	.00	795.46		795.46-	--
06 EQUIPMENT	1,000.00	.00		1,000.00	0
11 TELEPHONE SERVICES	3,570.00	305.86		3,264.14	9
16 NON-CAPITALIZED EQUIPMENT	.00	.00	1,364.18	1,364.18-	--
19 PRIOR YEAR BALANCE FORWARD	12,735.16-	.00		12,735.16-	--
21 INTERDEPARTMENTAL TRANSFERS	25,000.00-	1,715.32-		23,284.68-	--
OPERATIONS SUBTOTAL. . .	24,033.84	15,915.23	2,122.05	5,996.56	75
05 COMPUTING SERVICES	127.24	127.24		.00	100
OPERATIONS TOTAL	24,161.08	16,042.47	2,122.05	5,996.56	75
00 SALARIES	212,016.99	34,619.11	186,361.15	8,963.27-	104
07 EMPLOYEE BENEFITS	9,596.19	9,596.19		.00	100
PROJECT TOTAL.	245,774.26	60,257.77	188,483.20	2,966.71-	101

(3) PROJECT SUMMARY TO DATE BY SUBOBJECT	PROJECT BUDGET	EXPENDED TO DATE	OUTSTANDING ENCUMBRANCES	BALANCE	PCT. USED
00-AB CLASSIFIED STAFF		24,960.50	131,741.10		
00-AF FACULTY		9,131.36	45,656.80		
00-AH GRADUATE ASSISTANTS		527.25	8,963.25		
TOTAL SALARIES.	212,016.99	34,619.11	186,361.15	8,963.27-	104
01-AK OTHER EMPLOYEES		3,729.81			
01-AL STUDENTS		3,963.38			
TOTAL WAGES	3,000.00	7,693.19		4,693.19-	256
02-KA RESEARCH, SURVEYS, AND APPRAISAL		1,100.00			
TOTAL PERSONAL SERVICE CONTRACTS.	.00	1,100.00		1,100.00-	--
03-AA OFFICE SUPPLIES		860.90			
03-AC INSTRUCTION/LAB/MEDICAL SUPPLIES		4,665.69	462.24		
03-AH BUILDING MAINTENANCE SUPPLIES		104.90			
03-AS PARTS - EQUIPMENT		73.38			
03-AT FILM AND PHOTOGRAPHIC SUPPLIES		41.45			
03-AW PARTS - VEHICLES		.00	295.63		
03-BN SMALL EQUIPMENT ITEMS		355.83			
03-BW INTERDEPARTMENT SUPPLIES & SERVICES		1,109.66			
03-DD 1ST CLASS POSTAGE		6.92			
03-DS ROADRUNNER TOLLS		148.46			
03-FM DEMURRAGE		96.00			
03-HB DUPLICATING		11.29			
03-KB CONFERENCE REGISTRATION FEES		150.00			

ENVIRONMENTAL IMPACT APPRAISAL FOR THE CONTINUED OPERATION OF THE WASHINGTON STATE UNIVERSITY MODIFIED TRIGA REACTOR

Submitted to:

U.S. Nuclear Regulatory Commission

WASHINGTON STATE UNIVERSITY
NUCLEAR RADIATION CENTER
PULLMAN, WASHINGTON 99164

May, 1995

1.0 GENERAL

This Environmental Impact Appraisal for the continued operation of the Washington State University Modified TRIGA Reactor is submitted to enable the Commission to support and develop the EIA for the renewal of Facility License R-76. On January 23, 1974 the AEC staff concluded in the memorandum addressed to D. Skovholt and signed by D.R. Miller, "that there will be no significant environmental impact associated with the licensing of research reactors or critical facilities designed to operate at power levels of 2 MWt or lower and that no environmental impact statements are required to be written for the issuance of construction permits or operating licenses for such facilities." Thus no formal EIA is required for the extension of the operating license of Facility R-76 for the WSU TRIGA 1 MWt Research Reactor.

2.0 LOCATION OF FACILITY

The WSU TRIGA reactor is located in the Nuclear Radiation Center on the campus of Washington State University in Pullman, Washington. Pullman is a small town in the southeast corner of the State of Washington as shown in Figure 1 and has a total population, including the university of 23,500. The Palouse region surrounding the town is a rural agricultural area devoted to dry land farming.

The actual reactor site is east of Pullman and east of the main portion of the WSU campus as shown in Figure 2. The site is surrounded by university property used for grazing livestock as shown in the site photograph of Figure 3, and the closest occupied dwelling is 411 meters west of the facility. Additional details on the site are given in the facility SAR of May, 1979.

3.0 PHYSICAL CHARACTERISTICS OF THE FACILITY

The WSU reactor is a modified TRIGA reactor and operates with a core of mixed Standard and FLIP fuels. The reactor was originally designed to use MTR plate-type fuel but was converted to TRIGA fuel in 1967 by replacing the MTR fuel elements with 4-rod clusters of TRIGA fuel. The reactor is housed in the WSU Nuclear Radiation Center which is a 1200 square meter

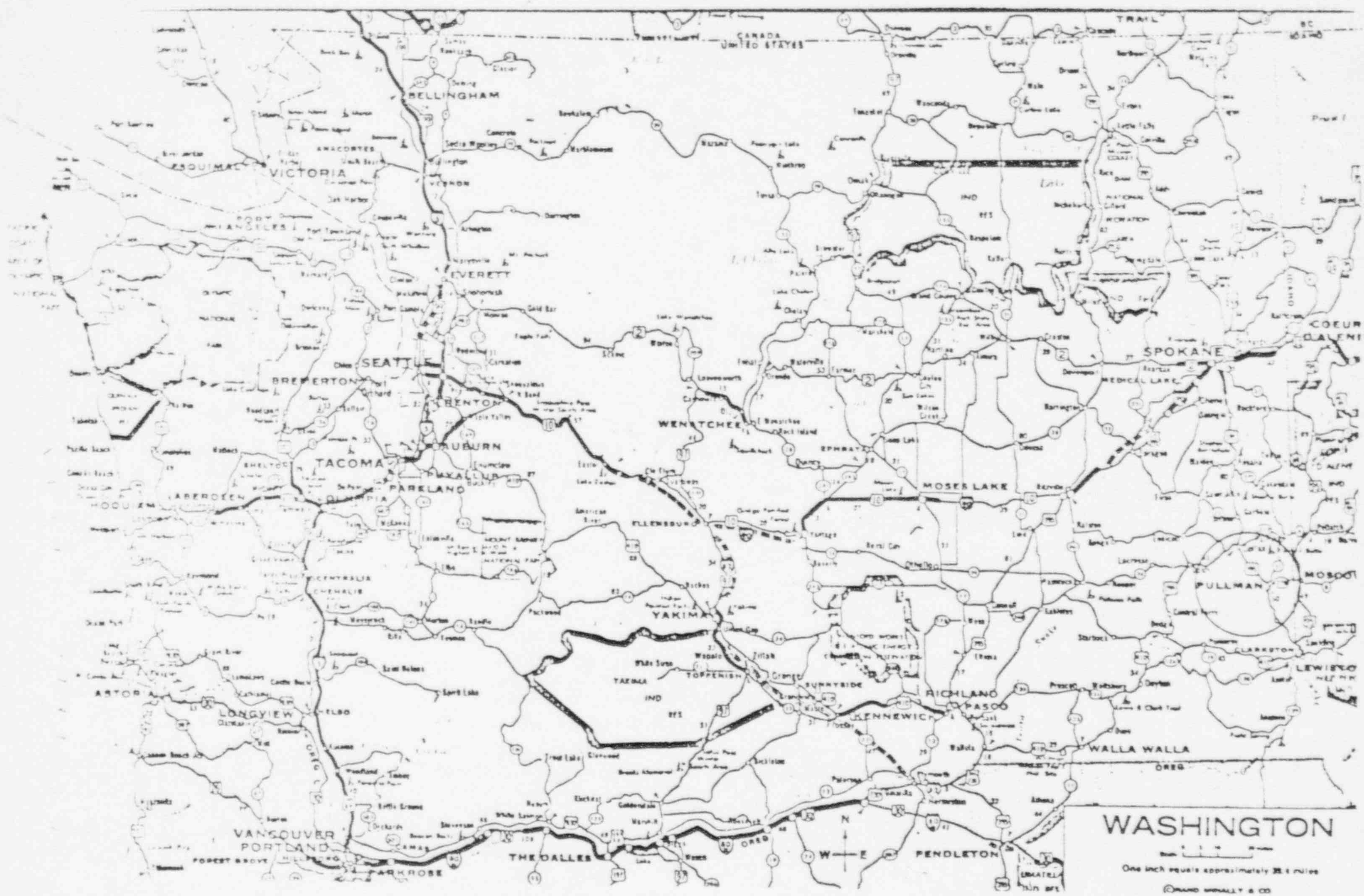
WASHINGTON
One inch equals approximately 35.4 miles
©RAND McNALLY & CO.
CANADA
UNITED STATES
BELLINGHAM
VICTORIA
EVERETT
SEATTLE
BREMERTON
RENTON
AUBURN
TACOMA
PUYALLUP
PARKLAND
OLYMPIA
ABERDEEN
HOQUIAM
CENTRALIA
CHEHALIS
LONGVIEW
KELSO
ASTORIA
VANCOUVER
PORTLAND
PARKROSE
THE DALLES
WENATCHEE
ELLENSBURG
YAKIMA
TOPPENISH
SUNNYSIDE
RICHLAND
PASCO
KENNEWICK
WALLA WALLA
PENDLETON
MOSES LAKE
EPHRATA
SPOKANE
MEDICAL LAKE
PULLMAN
CLARKSTON
TRAIL
N
W
E

Figure 1

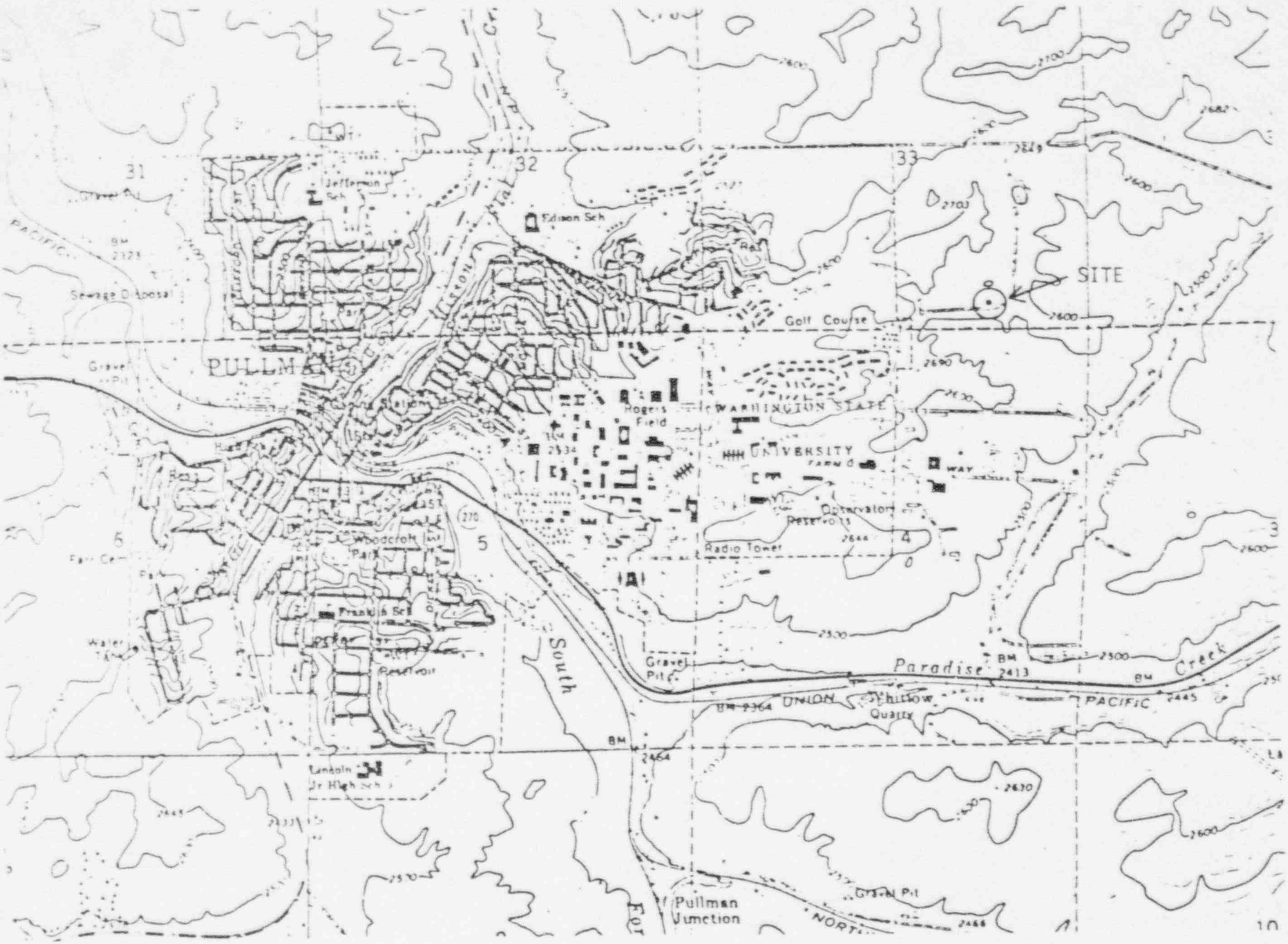
SITE
Golf Course
WASHINGTON STATE
UNIVERSITY
Rogers Field
Radio Tower
Observatory
Reservoirs
PULLMAN
Edison Sch
Jefferson Sch
Woodcroft Park
Franklin Sch
Reservoir
Sewage Disposal
Gravel Pit
Water Tank
Lincoln Jr High Sch
South
Paradise Creek
UNION PACIFIC
Shiflow Quarry
Pullman Junction
Gravel Pit
31
32
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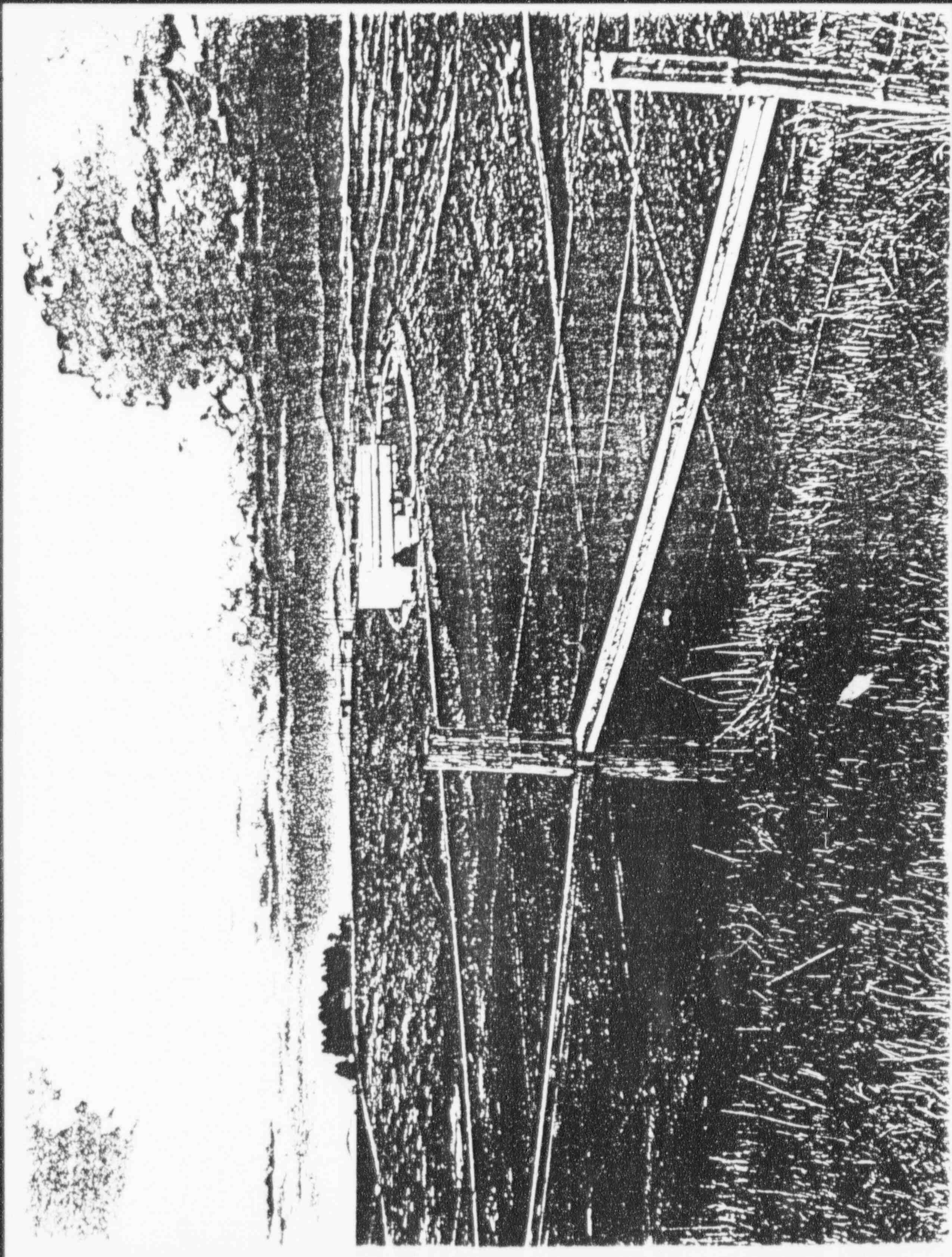
Figure 2



laboratory devoted to nuclear related research and educational activities. The core of the reactor is situated in a 242,000 liter water pool which functions as shield, moderator, and coolant.

The WSU modified TRIGA reactor, like all TRIGA type reactors, has very large prompt negative temperature coefficient, thus making the reactor inherently very safe. The kinetic behavior of TRIGA reactors permits them to be safely pulsed to very high power levels for a short duration. The pulse is automatically terminated by the effects of the large negative temperature coefficient. The WSU reactor operates at a maximum continuous steady state power level of 1 MWt and may be pulsed with a $2.50 insertion. The peak power during a pulse is on the order of 2000 MW.

4.0 ENVIRONMENT IN THE AREA

The reactor site lies approximately 3.2 kilometers east of the center of the town of Pullman and 1.6 kilometers east of the center of the WSU campus. The land surrounding the site for at least 400 meters in all directions is uninhabited grass land owned by the university and used for the grazing of livestock. Geologically the site is located at an elevation of 808 meters on the south slope of a typical Palouse formation hill.

Pullman is situated near the eastern margin of the Columbia Plateau and the associated lava flows. The site is thus underlaid with basaltic rock produced by horizontal lava flows. The bedrock was capped with silt and clay deposited during the Pleistocene Age to form the present topsoil of the Palouse Loess with their characteristic rolling hill topography. The Palouse formation (topsoil) at the reactor site is approximately 30 meters thick.

Pullman is located approximately 480 kilometers inland from the Pacific Ocean. The Cascade Mountains, which average more than two kilometers in height, separate the region from the coast. The combined effect of the distance from the ocean and the extensive mountain barrier produces a climate that is continental in character. However, because the prevailing winds blow inland from the Pacific Ocean, winters are somewhat warmer than might be expected 480 kilometers inland at a latitude of 47° north. Winters in Pullman are characterized by cloudy skies

and frequent snowstorms. On the average, the sun shines only about 30% of the time during the winter months.

During the summer months, the westerly winds weaken, and continental climatic conditions prevail. This causes rainfall, cloud cover, and relative humidity to be at their minimum; the daily mean temperature and daily temperature variation 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% of the time during the summer months.

One of the characteristics of the Palouse region is that of being a rather windy area. The average annual wind velocity is of the order of 16 km/hr. For the most part, winds peak in January averaging about 21 km/hr and the low occurs in July averaging about 11 km/hr. The wind velocity is greater than 5 km/hr 94% of the time and greater than 8 km/hr 76% of the time. The wind is from a westerly direction of the order of 60% of the time and an easterly direction 30% of the time.

The annual precipitation in the Pullman area is 50 centimeters and the annual average temperature is 8.7°C. The highest precipitation month is January with 6.8 centimeters and the lowest is July with 1 centimeter. The daily mean temperature peaks in July at 20°C. The mean daily minimum-to-maximum for the two extremes is 15.7°C and 5.7°C respectively.

There are no unique environmental or natural characteristics of the reactor site or archaeological or historical sites located within close proximity of the reactor site. The site is in a very low population density region and east of the main population concentrations of both the town of Pullman and the WSU campus. The population centers are also upwind of the site over 60% of the time.

5.0 ENVIRONMENTAL EFFECTS OF CONSTRUCTION

No modifications to the Facility or the site will be required for the continued operation of the WSU reactor. There are no exterior conduits, pipelines, electrical or mechanical structures or transmission lines attached to the reactor facility other than utilities services which are required for

other structures and laboratories on campus. Thus there will be no significant effects upon the terrain, vegetation, wildlife, nearby waters, or aquatic life due to construction-type activities.

6.0 ENVIRONMENTAL EFFECTS OF FACILITY OPERATION

(a) Water Use Consumption

Make-up water for both the reactor pool and wet cooling tower are required for operation of the reactor. The WSU campus has its own water system with water derived from wells independent of the Pullman water system. Pool make-up amounts to 20,000 liters per month on the average and the cooling tower requires 2100 liters per hour of reactor operation at full power. The total water consumption of the reactor cooling system is approximately 195,000 liters per month.

The required make-up water is readily available from the WSU campus water system and thus will have no impact on the Pullman water supply system.

(b) Heat Dissipation

The WSU TRIGA reactor has a maximum steady state power output of 1 MWt. The 1 MWt of heat generated by the reactor is dissipated by an evaporative mechanical draft cooling tower located on the north side of the facility. The evaporative cooling system cools the reactor pool and dissipates the heat generated by the reactor to the atmosphere through the latent heat of vaporization of water. On the average, the facility generates 1000 MW-h per year and thus approximately 1.6×10^6 kilograms of water vapor are added to the local atmosphere per year by the operation of the facility. In other words, an average of 4400 liters of water per day are added to the atmosphere at the site.

Evaporative cooling towers have the potential for crating visible plumes of water vapor under certain atmospheric conditions. The plume is a region of air with a higher temperature and higher water content than the ambient air. The climatic and atmospheric conditions at the site and the small amount of water involved preclude the development of a plume by the WSU reactor cooling tower during the summer months. However, during

the winter months a very small plume is sometimes produced that rises of the order of 30 meters into the air above the cooling tower. Fogging and icing conditions at the site are not affected by the operation of the cooling tower. The amount of water added to the local atmosphere annually by the cooling tower is really insignificant compared to the 50 centimeters annual precipitation in Pullman. Thus the water added to the atmosphere by the operation of the facility will have a minimal effect on the environment.

(c) Chemical Discharges (non-radioactive)

No chemical discharges are generated directly from the operation of the reactor. The chemical discharges into the sanitary waste system at the Nuclear Radiation Center are related to conventional chemical laboratory operations at the site and are not different than those of other laboratories on campus.

The blow-down of the cooling tower also discharges into the sanitary sewer system. The blow-down discharge amounts to 9300 liters per month on the average which contains an increased amount of total dissolved solids than the input potable water. The concentration factor will be less than 10 and this the increased TDS is not significant.

The cooling tower and associated heat exchanger, like all boilers and other water cooling systems on campus, are maintained by the WSU water treatment group. The standard campus water treatment involves the use of MOGUL WS164 water treatment liquid at the rate of 40 ppm plus 22 ppm of algicide. The incremental increase in the discharge of treated water by the operation of the reactor is, however, insignificant compared to the total campus discharge of such water into the sanitary sewage system. Thus the environmental effects related to chemical discharges created by the operation of the reactor are not significant.

(d) Radioactive Discharges

(1) Gaseous

The ventilation system of the reactor discharges 2.12 m^3/sec of air from the pool room into the atmosphere. The principal radionuclide contained in the

discharge air is Argon-41 which is produced by the activation of argon contained in air. The Argon-41 content of reactor pool room exhaust is continuously monitored with a special gamma-ray spectrometer set to detect Argon-41. Over the past 5 years the total average quantity of Argone-41 discharged from the facility amounted to 20.7% of the Technical Specification limit. On a concentration basis, taking into account the dilution of the atmospheric wake effect in the lee of the building, the 5 year average release concentration of Argon-41 was 2.1×10^{-10} µCi/cm³. The release concentration for Argon-41 given by the EPA for reactor facilities in 40 CFR 61, subpart I is 1.7×10^{-9} µCi/cm³ which is 58 times lower than the new 10 CFR 20 Appendix B, Table II, Column 1 limit for Argon-41 of 1.0×10^{-8} µCi/cm³. The actual release concentration over the past 5 years amounted to 2.1% of the 10 CFR 20 limit and 12% of the EPA limit. A small amount of tritium is produced in the pool water through neutron capture in the deuterium present in the pool water. Measurements of the ^{3}H level in the pool water of a number of TRIGA reactors including the WSU reactor are reported on Page 170 of the August, 1976 issue of Health Physics. Measurements made by the WSU Radiation Safety Office agree with the reported value for the WSU reactor of .045 µCi/l. The pool evaporation rate amounts to 560 liters per day and the pool room exhaust discharge is 1.834×10^{11} cm³ per day. If we make the conservative assumption that the ^{3}H content of the pool water and evaporated water are the same, then the pool room exhaust would contain 1.37×10^{-10} µCi/cm³ of tritium. This is significantly below the applicable limit in 10 CFR 20 of 1×10^{-7} µCi/cm³ and the EPA limit of 1.5×10^{-9}. No other significant quantity of gaseous radioactive material or particulate radioactive material with a half-life greater than eight days has been released by the facility during the past 10 years.

In the event of a Loss of Coolant Accident or the Design Basis Accident, the 1995 review analysis of this postulated accident has shown the gaseous radioactive discharges to be minimal. The worst case whole body dose from a cloud of fission products discharged from the facility as a result of the DBA is only 1.28 mrem/hr. The worst case maximum thyroid dose outside the facility for a 3% halogen release was found to be 17.4 mrem/hr. Thus no realistic hazard to the general public would result from the DBA or a LOCA.

(2) Liquids

No radioactive liquids are generated by the operation of the reactor in and by itself. However, the nuclear research and educational activities t the Nuclear Radiation Center generate radioactive liquids from radiochemistry experiments and from activation analysis activities. All hot drains from the laboratory flow into a holdup tank system which is monitored and diluted as necessary before being discharged into the sanitary sewer. Over the past 3 years the radioactive liquid released from the holdup tanks, on the average, contained 4×10^{-8} $\mu Ci/cm^3$ or about 10% of the applicable release limit and amounts to about .5 μCi/month.

Radiation Safety at WSU has, for over 10 years, monitored the Radiochemistry level in the waters in the vicinity of WSU including the South Fork of the Palouse River, local tap water, and sewage treatment plant effluent. An increase in the activity levels attributable to the operation of the WSU TRIGA reactor has never been detected.

(3) Solids

The only solid radioactive waste generated directly by the operation of the reactor is spent ion exchange resin. Approximately .3 cubic meters of spent resin is disposed of each year. It is estimated that the long-lived components of the activity in the spent resin amounts to about .1 Ci/yr.

The entire WSU campus generates of the order of 8 cubic meters of solid radioactive waste annually containing approximately .5 curies of activity. This solid waste is predominantly generated by research activities in university laboratories other than the Nuclear Radiation Center utilizing long-lived purchased radionuclides. Thus the incremental increase in solid wastes generated by the operation of the reactor is minimal. All solid wastes are transferred to the Nuclear Engineering Company of Richland, Washington for disposal.

(e) Radiation Levels

An extensive Environmental Radiation Monitoring Program as instituted at the WSU Nuclear Radiation Center in July of 1974. The program involves measuring the integrated radiation exposure for a period of three months at 40 points at the site and associated environs. Commercially available thermoluminescent dosimeters (TLD's) of the $CaSO_4$:Dy type provided and processed by the Radiation Detection Company, Sunnyvale, California are utilized.

Table I lists the average exposure rate above ambient background per megawatt hour of reactor operation for a number of locations at the site. The two highest exposure points are on the roof directly above the pool and at the freight door to the pool room. The maximum possible on-site exposure at a readily accessible location would be to an individual standing at the pool room freight door for the 1000 hours per year that the reactor operates. The total maximum annual exposure a this on-site point would be 87 mrem/year.

The exposure rates at points from 50 meters to 24 kilometers from the Nuclear Radiation Center have also been monitored quarterly since 1974. The average exposure rate at the 24 locations involved is 188 ± 30 μR per day. No statistically significant variations in the above background exposure rates at the sample locations have been observed or any exposure attributable to the operation of the WSU reactor. In addition, the average exposure rates at these locations which are 50 meters from the site are not

statistically different on a quarterly basis than the average of the background exposure rates at 17 locations in the State of Washington monitored by the State of Washington Department of Emergency Services. Thus no significant effect on the radiation levels in the environment surrounding the facility has been observed to date.

7.0 ALTERNATIVES TO CONTINUED OPERATION OF THE FACILITY

There are no suitable or more economical alternatives which can accomplish both the educational and research objectives of the facility. These objectives include but are not limited to: the training of students in the operation of nuclear reactors; the training of students in the use of radioisotopic tracer techniques; the production of radioisotopes for use in numerous areas of the physical, biological, and animal sciences ;the training of students and research applciations of trace element analysis by neutron activation analysis; and also a demonstration too! to familiarize the student body and general public with nuclear reactors and their operation.

In addition, the WSU Reactor Facility is in the process of establishing and licensing a Medical Therapy Facility for human therapy using the BNCT method of cancer therapy. The BNCT method can only be done at a nuclear reactor facility and thus there is no alternative to this new, important cancer treatment methodology.

8.0 SHORT-TERM EFFECTS VERSUS LONG-TERM GAIN OF FACILITY OPERATION

One of the chief objectives of any institution of higher education is to increase the body of knowledge avai ible to mankind and to impart that knowledge to individuals. Accordingly, it is very difficult to compare the long-term gains from the operation of a research reactor in relation to the short-term environmental effects. However, the total environmental effects of the WSU TRIGA reactor and associated Nuclear Radiation Center are not significantly different from other research laboratories at a typical university. For the most part, the cumulative long-term benefits of university research activities far outweigh the environmental effects of such activities. This would also be true for the continued operation of the WSU reactor.

9.0 COST BENEFIT ANALYSIS

The facilities at the Nuclear Radiation Center represent an investment of the order of $2 million dollars. If the facility were shut down, the benefits derived from this investment would drop to zero. On the other hand, continued operation would allow the continuation of 10 ongoing research programs and the completion of about 8 graduate thesis research projects per year. The benefits also include the educational objectives mentioned in Section 6.0 and the new BNCT cancer therapy project being undertaken. Considering the minimal environmental effects of the continued operation of the rector as previously cited in this report, the environmental cost effects are very small compared to the benefits to be derived from continued operation.

TABLE 1

Median Exposure Rates per Megawatt Hour of Reactor Operation
in Close Proximity to the Nuclear Radiation Center

Location	(Adjacent to Room)	Exposure (μR/MW-Hr)
Front Entrance	50V	32
Pool Room Freight Door	201	87
North Side of Building	201B	10
Roof above Control Room	201B	16
Roof above Pool	201	152
Roof above Laboratory Area	214	0
West Side Door at Beam Room	2X	14
Storage Building	217A	21
Lower Loading Dock	123A	17

REVISED DESIGN BASIS ACCIDENT ANALYSIS FOR THE W.S.U. TRIGA REACTOR

1.0 INTRODUCTION

The Design Basis Accident for a TRIGA reactor is defined as the loss of the integrity of the fuel cladding of one fuel rod in air. The hazard associated with this theoretical accident is thus the effects of the postulated fission product release within the facility and to the surrounding environment. The D.B.A. for the W.S.U. TRIGA reactor was originally analyzed in the Safety Analysis for converting the W.S.U. TRIGA reactor to FLIP fuel of May, 1974. This revised analysis uses the same basic data as used in the previous analysis but the effects are calculated using more recent analysis methods and guide lines published by the Federal Government (1).

2. FISSION PRODUCT INVENTORY

The fission product release fraction for TRIGA-type reactor fuel has been measured experimentally (2) and documented before the AEC hearings on the Columbia reactor as being 1.5×10^{-5} at a fuel temperature of 300°C. The release fraction, FR, is, however, a function of the fuel temperature, T, in °C given by the relationship (2):

$$FR = 1.5 \times 10^{-5} + 3.6 \times 10^{3} \, EXP - (1.34 \times 10^{4}/T + 273).$$

Assuming a fuel temperature of 500°C, the release fraction is calculated to be 1.2×10^{-4} by the above relationship. A release fraction of 1.2×10^{-4} will be used in the calculations for the D.B.A.

A power density of 30 kw per fuel rod and an infinite irradiation time will also be assumed for the D.B.A. Under these conditions the fission product inventory for one TRIGA fuel rod and the associated released fission products are tabulated in Tables 1 and 2. This tabulation was derived from the basic data of Perkins and King (3) along with the documented fact (2) that only the gaseous fission products escape when the cladding of a TRIGA fuel rod ruptures. The data in Tables 1 and 2 are comparable to fission product inventory recently calculated for the Bangladesh TRIGA reactor by G.A. after correcting for reactor power level.

TABLE 1
SOLUBLE GASEOUS FISSION PRODUCTS
CONTAINED IN AND RELEASED FROM A SINGLE TRIGA FUEL ROD*

Isotope	Saturated Inventory Ci	Released Activity mCi	Half-Life
Br-82	40	4.8	35.3 hr
83	137	16.4	2.3 hr
84	253	30.4	31.8 min
85	330	39.6	3.0 min
87	780	93.6	55.0 sec
Total Br	1540	184.8	
I-130m	260	31.2	9.2 min
131	734	88.1	8.1 days
132	1115	133.8	2.3 hr
133	1672	200.6	21.0 hr
134	2027	243.2	54.0 min
135	1546	185.5	6.8 hr
136	785	94.2	86.0 sec
Total I	8139	976.6	
Kr-83m	137	16.4	1.9 hr
85m	330	39.6	4.4 hr
85	67	8.0	10.7 yr
87	634	76.1	78.0 min
88	912	109.4	2.8 hr
89	1115	133.8	3.2 min
Total Kr	3195	383.3	
Xe-131m	7	0.8	12.0 days
133m	40	4.8	2.3 days
133	1672	200.6	5.3 days
135m	457	54.8	15.0 min
135	1621	194.5	9.0 hr
137	1545	185.4	3.9 min
138	1166	139.9	17.0 min
Total Xe	6508	780.8	

Total Released Soluble Gaseous Fission Products = 1.16 Ci
Total Gamma Emitters = 1.03 Ci
Total Beta Emitters = 1.16 Ci

*Power Density = 30 kw/rod, fuel temperature = 500°C, release fraction 1.2×10^{-4}

3. WHOLE BODY RADIATION EXPOSURE IN POOL ROOM

The whole body exposure for each fission product radionuclide released as a result of a postulated single fuel element cladding failure is given in Table 2. This table contains all the parameters involved with the dose calculation including the DCF (Dose Conversion Factor) for each radionuclide taken from the 1992 EPA document: "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" (1). The DCF's include the sum of the dose from external radiation exposure from an infinite radioactive hemispherical cloud and exposure due to inhalation of each airborne radionuclide.

The total dose to an individual in the Pool Room of the WSU TRIGA reactor for 5 minute and 1 hour exposure times are given in Tables 4 and 5. Table 4 assumes a 100% noble gas release and a 25% halogen release. Table 5 assumes a 100% noble gas release and a 3% halogen release (most realistic case).

4. THYROID RADIATION EXPOSURE IN POOL ROOM

The thyroid radiation exposure for each iodine radionuclide in a single fuel element and 100% escape into the pool room is given in Table 3. The total thyroid dose for 5 minute and 1 hour exposure times is given in Tables 4 and 5. Table 4 assumes a 25% halogen release and Table 5 assumes a 3% halogen release.

TABLE 2
POOL ROOM FISSION PRODUCT CONCENTRATIONS
AND ASSOCIATED EXPOSURE RATES FOR
SINGLE FUEL ELEMENT CLADDING FAILURE (a)

Isotope	Activity Released in mCi (b)	Release Concentration in μCi/cm³ (c)	DCF in rem per μCi/cm³/hr (d)	Dose in mrem/hr (b)
Br-82	4.8	4.8×10^{-6}	1250	6.0
83	15.8	1.58×10^{-5}	83	.13
84	25.8	2.58×10^{-5}	125	3.1
85	7.0	7.0×10^{-6}	115	.8
Total Bromine Dose Rate (100% Br escape) =				10
I-131	88.1	8.81×10^{-5}	220	19.4
132	129	1.29×10^{-4}	1400	181
133	201	2.01×10^{-4}	350	70.4
134	221	2.21×10^{-4}	1600	353
135	186	1.86×10^{-4}	950	177
136	2.5	2.48×10^{-6}	110	.3
Total Iodine dose rate (100% I escape) =				801
Kr-83m	15.7	1.57×10^{-5}	100	1.6
85m	39.6	3.96×10^{-5}	93	3.7
85	8.0	8×10^{-6}	1.3	.01
87	71.2	7.12×10^{-5}	510	36.2
88	106	1.06×10^{-4}	1300	138
89	26	2.6×10^{-5}	1200	31.2
Total krypton dose rate =				211
Xe-131m	.8	8×10^{-7}	4.9	0
133m	4.8	4.8×10^{-6}	17	.08
133	201	2.01×10^{-4}	140	28.1
135m	28	2.8×10^{-5}	250	7.0
135	195	1.95×10^{-4}	140	27.3
137	49	4.9×10^{-5}	110	5.4
138	103	1.03×10^{-4}	710	73.1
Total xenon dose rate =				141

(a) Fracture and release of fission products in our TRIGA Fuel Element with a 1.2×10^{-4} release fraction.
(b) Averaged over a 15 minute period.
(c) Pool Room volume = $1 \times 10^9 cm^3$.
(d) Values from EPA-400-R-92-001, Manual of Protective Action Guides and Protective Actions for Nuclear Incidents. Includes both inhalation and external exposure effects.

TABLE 3
SINGLE FUEL ELEMENT FAILURE
Total Iodine Release Thyroid Exposure (a)

Isotope	Activity Released in mCi (b)	Release Concentration in µCi/cm³ (c)	DCF in rem per µCi/cm³/hr (d)	Dose in rem/hr
I-131	88.1	8.81×10^{-5}	1.3×10^{6}	114
132	129	1.29×10^{-4}	7.7×10^{3}	1.0
133	201	2.01×10^{-4}	2.2×10^{5}	44.2
134	221	2.22×10^{-4}	1.3×10^{3}	.3
135	186	1.86×10^{-4}	3.8×10^{4}	7.1
Total thyroid dose rate (100% Iodine escape) =				166.6

(a) Fracture and release of fission products in our TRIGA Fuel Element with a 1.2×10^{-4} release fraction.
(b) Averaged over a 15 minute period.
(c) Pool Room volume = 1×10^{9}cm³.
(d) Values from EPA-400-R-92-001, Manual of Protective Action Guides and Protective Actions for Nuclear Incidents. Includes both inhalation and external exposure effects.

TABLE 4
WORST CASE DOSE TO PERSONNEL IN THE REACTOR POOL ROOM:
SINGLE FUEL ELEMENT FAILURE WITH POOL WATER LOSS.
RELEASE: 100% NOBLE GASES, 25% HALOGENS

Exposure Time	Whole Body (mrem)	Thyroid (mrem)
5 min	46	3,470
1 hr	555	41,650

TABLE 5
WORST CASE DOSE TO PERSONNEL IN THE REACTOR POOL ROOM:
SINGLE FUEL ELEMENT FAILURE WITHOUT POOL WATER LOSS.
RELEASE: 100% NOBLE GASES, 3% HALOGENS

Exposure Time	Whole Body (mrem)	Thyroid (mrem)
5 min	31	417
1 hr	376	4,998

5. DISCHARGE OF THE FISSION PRODUCTS INTO THE ENVIRONMENT

The rate at which fission products from the pool room are released into the environment in a D.B.A. condition is dependent upon the rate of removal of pool room air by the pool room ventilation system. In the normal operation mode, air is exhausted from the pool room at the rate of 4500 cfm or 2.12×10^6 cm^3/sec. In the dilution mode, 300 cfm of air from the pool room is passed through a HEPA filter system, diluted with 1700 cfm of outside air and discharged into the atmosphere. In the dilution mode, 2000 cfm of air is discharged or 9.44×10^5 cm^3/sec with a dilution factor of 6.67. If the ventilation system is off, the release to the environment would only be by leakage from a sealed building which is estimated to be of the order of 100 cfm or 4.72×10^4 cm^3/sec. In the dilution mode the HEPA filter would remove at least 90% of the iodine from the exhaust air.

The activity of each radionuclide exhausted from the facility, Xi in μCi per cm^3 at any time after t = 0 is given by the equation

$$Xi = A_i e^{-(\lambda_i + \ell/V)t}.$$

where A_i = the concentration of the ith isotope in the pool room at t = 0 in μCi/cm^3

ℓ = the building exhaust rate in cm^3/sec

V = the volume of pool room in cm^3

λ_i = the decay constant of the ith isotope in sec^{-1}

t = time after t = 0 in seconds.

6. DILUTION OF DISCHARGE IN THE LEE OF THE BUILDING

The gaseous radioactive material discharged from the facility ventilation system will be diluted by atmospheric air in the lee of the building due to turbulent wake effects. The dilution is proportional to the product of the cross sectional area of the building times the wind speed. That is,

ϕ = dilution factor = $1/cAu$ (sec/cm^3)

C = constant (2 to .5), select 1 (cm^3/m^3)

where A = building cross-sectional area in square meters

u = wind speed in meters/sec.

Thus for a nominal 2/msec wind velocity (4.4 mph)* and a 56 x 28 ft building, the dilution factor is $\phi = 3.4 \times 10^{-3}$.

7.a. WHOLE BODY RADIATION EXPOSURE AND THYROID EXPOSURE OUTSIDE THE FACILITY

The activity discharged into the atmosphere as a result of the D.B.A. under three modes of operation of the ventilation system are given in Tables 6, 7, and 8 along with the thyroid and whole body exposure to a person outside the facility in each case. The activities reported include a correction for the atmosphere dilution factor in the lee of the building and in the case of the dilution mode, for the dilution factor for this mode of operation.

*Average annual wind speed is in excess of 5 mph (14).

TABLE 6
ENVIRONMENTAL FISSION PRODUCT CONCENTRATIONS
AND ASSOCIATED EXPOSURE RATES FOR
SINGLE FUEL ELEMENT CLADDING FAILURE
(Ventilation system on, no radionuclide decay)[a]

Isotope	Pool Room Conc. in µCi/cm³	Environmental Conc. in µCi/cm³	DCF in rem per µCi/cm³/hr	Dose in mrem/hr
Br-82	4.8×10^{-6}	1.63×10^{-8}	1250	.0204
83	1.58×10^{-5}	5.37×10^{-8}	83	.0044
84	2.58×10^{-5}	8.78×10^{-8}	125	.0110
85	7.0×10^{-6}	2.38×10^{-8}	115	.00274
Total Bromine Dose Rate (100% Br escape) =				.0386
I-131	8.81×10^{-5}	3.00×10^{-7}	220	.0659
132	1.29×10^{-4}	4.39×10^{-7}	1400	.614
133	2.01×10^{-4}	6.84×10^{-7}	350	.239
134	2.21×10^{-4}	7.52×10^{-7}	1600	1.203
135	1.86×10^{-4}	6.33×10^{-7}	950	.601
136	2.48×10^{-6}	8.44×10^{-9}	110	.00093
Total Iodine dose rate (100% I escape) =				2.724
Kr-83m	1.57×10^{-5}	5.34×10^{-8}	100	.0053
85m	3.96×10^{-5}	1.35×10^{-7}	93	.0125
85	8×10^{-6}	2.72×10^{-8}	1.3	.000035
87	7.12×10^{-5}	2.42×10^{-7}	510	.1235
88	1.06×10^{-4}	3.605×10^{-7}	1300	.4687
89	2.6×10^{-5}	8.84×10^{-8}	1200	.10612
Total krypton dose rate =				.716
Xe-131m	8×10^{-7}	2.72×10^{-8}	4.9	.00001
133m	4.8×10^{-6}	1.63×10^{-8}	17	.00028
133	2.01×10^{-4}	6.84×10^{-7}	140	.0957
135m	2.8×10^{-5}	9.52×10^{-8}	250	.0238
135	1.95×10^{-4}	6.63×10^{-7}	140	.0929
137	4.9×10^{-5}	1.67×10^{-7}	110	.0183
138	1.03×10^{-4}	3.50×10^{-7}	710	.2487
Total xenon dose rate =				.4797

(a) Worst case assuming the ventilation systems is ON and discharge equals pool room concentration and only dilution effect is that of wake effect in the lee of the reactor bulding.

TABLE 6A
SINGLE FUEL ELEMENT FAILURE
Environmental Thyroid Exposure for Total Iodine Release*

Isotope	Environmental Release Concentration in μCi/cm³	DCF in rem per μCi/cm³/h	Dose in rem/hr
I-131	3.00×10^{-7}	1.3×10^{6}	.390
132	4.39×10^{-7}	7.7×10^{3}	.0034
133	6.84×10^{-7}	2.2×10^{5}	.150
134	7.52×10^{-7}	1.3×10^{3}	.001
135	6.33×10^{-7}	3.8×10^{4}	.034
Total thyroid dose rate (100% Iodine escape) =			.58

TABLE 6B
TOTAL ENVIRONMENTAL WORST CASE EXPOSURE:*
SINGLE FUEL ELEMENT FAILURE WITH POOL WATER LOSS.
VENTILATION SYSTEM IN NORMAL EXHAUST MODE
RELEASE: 100% NOBLE GASES, 25% HALOGENS

Exposure Time	Whole Body (mrem)	Thyroid (mrem)
5 min	.157	12
1 hr	1.89	145

TABLE 6C
TOTAL ENVIRONMENTAL WORST CASE EXPOSURE:*
SINGLE FUEL ELEMENT FAILURE WITHOUT POOL WATER LOSS.
VENTILATION SYSTEM IN NORMAL EXHAUST MODE
RELEASE: 100% NOBLE GASES, 3% HALOGENS

Exposure Time	Whole Body (mrem)	Thyroid (mrem)
5 min	.106	1.45
1 hr	1.28	17.4

*Single fuel element failure, ventilation system in normal exhaust mode, no radioactive decay correction, only dilution effect is that of wake effect in the lee of the reactor building.

TABLE 7
ENVIRONMENTAL FISSION PRODUCT CONCENTRATIONS
AND ASSOCIATED EXPOSURE RATES FOR
SINGLE FUEL ELEMENT CLADDING FAILURE
(Ventilation system in dilution mode, no radionuclide decay)[a]

Isotope	Pool Room Conc. in μCi/cm³	Environmental Conc. in μCi/cm³	DCF in rem per μCi/cm³/hr	Dose in mrem/hr
Br-82	4.8×10^{-6}	2.44×10^{-9}	1250	.00304
83	1.58×10^{-5}	8.05×10^{-9}	83	.00066
84	2.58×10^{-5}	13.3×10^{-9}	125	.00165
85	7.0×10^{-6}	3.57×10^{-9}	115	.00041
Total Bromine Dose Rate (100% Br escape) =				.00578
I-131	8.81×10^{-5}	4.50×10^{-8}	220	.0099
132	1.29×10^{-4}	6.58×10^{-8}	1400	.0921
133	2.01×10^{-4}	10.3×10^{-8}	350	.0358
134	2.21×10^{-4}	11.3×10^{-8}	1600	.1804
135	1.86×10^{-4}	9.49×10^{-8}	950	.0901
136	2.48×10^{-6}	0.13×10^{-8}	110	.0001
Total Iodine dose rate (100% I escape) =				.408
Kr-83m	1.57×10^{-5}	8.01×10^{-9}	100	.00079
85m	3.96×10^{-5}	2.02×10^{-8}	93	.00187
85	8×10^{-6}	4.08×10^{-9}	1.3	.0
87	7.12×10^{-5}	3.63×10^{-8}	510	.01852
88	1.06×10^{-4}	5.40×10^{-8}	1300	.07270
89	2.6×10^{-5}	1.33×10^{-8}	1200	.01591
Total krypton dose rate =				
Xe-131m	8×10^{-7}	4.08×10^{-9}	4.9	.0
133m	4.8×10^{-6}	2.44×10^{-9}	17	.00004
133	2.01×10^{-4}	1.03×10^{-7}	140	.01435
135m	2.8×10^{-5}	1.43×10^{-8}	250	.00357
135	1.95×10^{-4}	9.99×10^{-8}	140	.01393
137	4.9×10^{-5}	2.50×10^{-8}	110	.00274
138	1.03×10^{-4}	5.25×10^{-8}	710	.03729
Total xenon dose rate =				.0719

(a) Worst case dilution mode assuming the ventilation systems is in dilution mode and discharge equals initial pool room concentration diluted by the wake effect in the lee of the reactor building and the effects of the dilution mode but no radioactive decay correction or time dependent exhaust effect.

TABLE 7A
SINGLE FUEL ELEMENT FAILURE
Environmental Thyroid Expousre for Total Iodine Release,
Ventilation System in Dilution Mode, HEPA Filter Not Functioning*

Isotope	Environmental Release Concentration in μCi/cm³	DCF in rem per μCi/cm³/hr	Dose in rem/hr
I-131	4.50×10^{-8}	1.3×10^{6}	.0585
132	6.58×10^{-8}	7.7×10^{3}	.0005
133	10.3×10^{-8}	2.2×10^{5}	.0225
134	11.3×10^{-8}	1.3×10^{3}	.00015
135	9.49×10^{-8}	3.8×10^{4}	.0051
Total thyroid dose rate (100% Iodine escape) =			.0867

TABLE 7B
TOTAL ENVIRONMENTAL WORST CASE EXPOSURE:*
SINGLE FUEL ELEMENT FAILURE WITH POOL WATER LOSS.
VENTILATION SYSTEM IN DILUTION MODE
RELEASE: 100% NOBLE GASES, 25% HALOGENS

Exposure Time	Whole Body (mrem)	Thyroid (mrem)
5 min	.024	1.8
1 hr	.28	21.7

TABLE 7C
TOTAL ENVIRONMENTAL WORST CASE DILUTION MODE EXPOSURE:*
SINGLE FUEL ELEMENT FAILURE WITHOUT POOL WATER LOSS.
VENTILATION SYSTEM IN DILUTION MODE
RELEASE: 100% NOBLE GASES, 3% HALOGENS

Exposure Time	Whole Body (mrem)	Thyroid (mrem)
5 min	.016	.22
1 hr	.19	2.60

*No radioactive decay corrections, HEPA filter not working. Only corrections are t = 0 dilution effects.

7b. DECAY CORRECTED ENVIRONMENTAL EXPOSURE ESTIMATE

In order to simplify the calcualtion o f the effects of fission product release into the environment from the pool room, including radioactive decay of the isotopes involved, the released fission products have been lumped into four groups of isotopes with similar half-lives. The mean weighted half-life of each group along with the mean weighted DCF for each group and the total quantity of radioactive material in curies was calculated for each group. The group data has then been used to calculate the environmental radiation exposure as a function of time given in tables 9 and 10.

a. Group 1. Half-life 0 to 30 min

Effective half-life = 14.1 min

Weighted mean DCF = 521

Total group activity = 353 mCi at t = 0

b. Group 2. Half-life 31 min to 3.0 hr

Effective half-life = 153 min

Weighted mean DCF = 1200

Total group activity = 176 mCi at t = 0

c. Group 3. Half-life = 3.1 hr to 10 hr

Effective half-life = 8.5 hr

Weighted mean DCF - 258

Total group activity = 233 mCi at t = 0

d. Group 4. Half-life - 11 hr to ∞

Effective half-life = 5.38 days

Weighted mean DCF = 142

Total group activity = 204 mCi

One group iodine approximation at

Effective half-life = 15 hrs

Weighted mean DCF - 1.05×10^6 rem/μCi cm³/hr

Total activity (3% halogen release) of t = 0 = 5.0 mCi

The pool room thyroid dose rate at t = 0 using the one group approximation, is 5.3 rem/hr which is comparable to the 5 rem given in table 5.

Pool Room Dose at t = 0 Using Four Group Data

Group	Activity mCi	Pool Room μCi/cm^3	DCF in rem per μCi/cm^3/hr	Dose in mrem/hr
1	353	3.53×10^{-4}	521	182
2	126	1.76×10^{4}	1200	211
3	233	2.33×10^{4}	258	60
4	205	2.04×10^{-4}	182	29
	Total			482

The previous result shown in table 5 is 371 mrem/hr so at least at t = 0 the group method is conservative.

8. ENVIRONMENTAL DOSE RATES AS A FUNCTION OF TIME

(a) Normal Ventilation System Operation Mode.

In the case that the ventilation system is left in the normal operation mode, radioactive decay is an insignificant consideration because the volume of the air in the pool room is exhausted over seven times in one hour. The only significant effect is the dilution by the exhaust system. In this case the environmental dose rate outside the facility as a function of time is given by $D(t) = D(t{=}0)\, e^{-(\ell/v)t}$ where $D(t{=}0)$ is the dose rate at t = 0, ℓ = exhaust rate, v = pool room volume, and t is the time.

TABLE 10
ENVIRONMENTAL DOSE RATES AS A FUNCTION OF TIME*
VENTILATION SYSTEM IN NORMAL OPERATIONAL MODE

Time (min)	$(\ell/v)t$	D(t)/D(t=0)	D(t) in mrem/hr Thyroid	D(t) in mrem/hr Whole Body
0	1	1	17.4	1.28
10	1.28	.28	4.9	.36
20	2.56	.08	1.4	.10
30	3.84	.021	.04	.003
60	7.68	.00046	.08	0
120	15.76	2.13×10^{-7}	0	0

*Assume 100% nobel gas release and 3% halogen release.

(b) Dilution Mode Operation

In the dilution mode, Pool Room air is diluted with air drawing from outside the facility by a factor of 6.67 before being discharged into the environment. Also the air is passed through a HEPA filter which will remove all particulate matter as well as most of the halogens. However, for worst case calculational purposes, it will be assumed that the dilution effect is the only mitigating effect.

TABLE 11
WORST CASE ENVIRONMENTAL WHOLE BODY DOSE
AS A FUNCTION OF TIME WITH THE VENTILATION SYSTEM OPERATING
IN THE DILUTE MODE, HEPA FILTER NOT FUNCTIONING

Time (hrs)	$(\lambda + \ell/v)t$	D(t)/D(t=0)	D(t) in mrem/hr Whole Body
0	1	1	.19
1	.0132	.986	.19
4	.0527	.949	.18
8	.1055	.90	.17
24	.3164	.729	.14
48	.6327	.531	.11
96	1.268	.282	.05
144	1.898	.15	.03
320	4.218	.015	.03

TABLE 12
ONE GROUP IODINE ENVIRONMENTAL EXPOSURE RESULTS FOR 3% IODINE RADIONUCLIDE ESCAPE DROM ONE FULE ELEMENT. VENTILATION SYSTEM OPERATING IN DIULTION MODE, HEPA FILTER NOT WORKING[a]

Time (hrs)	$(\lambda + l/v)t$[b]	D(t)/D(t=0)	Thyroid Exposure Rate mrem/hr
0	1	1	2.7
.5	.2603	.771	2.08
1	.521	.594	1.60
2	1.042	353	.95
4	2.984	.124	.33
8	4.168	.015	.041
12	6.252	.0019	.0051
24	12.50	0	0

(a) Total dilution effect at t = 0 is 1962.
(b) $(\lambda + l/v) = .521\ hr^{-1}$

9.0 SUMMARY OF RESULTS OF D.B.A.

The preceding calculations on the consequences of the D.B.A. indicate that the only significant worst case radiation expsoure is the thyroid dose to a person in the pool room. The conditions necessary to produce this exposure are the failure of the cladding of one fuel rod along with a complete loss of pool water. The maximum possible radiation exposure to an individual outside the facility under the postulated conditions is minimal. Thus, no realistic hazard to the general public would result from the Design Base Accident.

REFERENCES

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