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50-188

Daniel E. Hughes, Project Manager
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New, Research and Test Reactors Program
Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation

DATE: 27 September 2005

SUBJECT: **Response to July 28, 2005 Letter:** ***Kansas State University – Request for Additional Information Letter No. 2 Re: License Renewal for the Kansas State University Nuclear Reactor Facility Environmental Report*** **(TAC NO. MB6326)**

Dear Mr. Hughes:

A license renewal request was submitted for the Kansas State University in 2002, and the facility is currently operating under "timely renewal" provisions. USNRC review generated 3 Requests for Additional Information (RAI): the initial RAI applicable to the proposed KSU Reactor Safety Analysis Report and Technical Specifications (TAC MB7966 March 18, 2004 ADAMS accession ML040780231), a second RAI for the KSU Reactor Emergency Plan (April 28, 2005; ADAMS accession ML051120255), and a third RAI for the Environmental Report (TAC MB6236 July 28, 2005; ADAMS accession ML051960081). The initial RAI was addressed in two parts, the 1st part addressing the Safety Analysis Report (excluding Technical Specifications) submitted in 2004, and 2nd part of the initial RAI (Technical Specifications and minor corrections to the Safety Analysis Report) combined with response to the 2nd RAI (addressing the Emergency Plan), submitted in 2005. This transmittal addresses the 3rd RAI (Environmental Report), completing responses to the RAIs to date.

A revision to the proposed Environmental Report was developed to incorporate responses to the RAI, proposed increase in maximum steady state power level limit (i.e., compared to the original submission), and minor editorial changes for clarity, consistency and grammar. The changes were tabulated to indicate section revised, revised text (where appropriate), and the reason for the change. The revised Environmental Report (incorporating RAI responses) is attached with the tabulation of changes.

If you have any questions or comments concerning this matter, you may contact me at 785-532-6657 or whaley@ksu.edu.

I verify under penalty of perjury that the foregoing is true and correct,

Executed on 28 September 2005,

P. M. Whaley

A020

Docket No. 50-188
Enclosures: as indicated

Attachment I Revision to Proposed KSU Environmental Report		
SECTION	REVISION	REASON
TOC	Added section 4.7	RAI 9
Section 1, page 1	This environmental report is prepared in accordance with 10 CFR 51 as part of the nuclear reactor license renewal at Kansas State University (KSU). The KSU TRIGA Mark II nuclear reactor (KSU TRIGA) is a light-water cooled and moderated reactor using uranium fuel. The reactor has been operated since 1968 at thermal power levels up to 250 kW, and an application has been made to increase the maximum power level to 1,250 kW…	Changed "is now operated" to "has been operated since 1968" for completeness of information; changed all references to reactor from various terms to "KSU TRIGA"
Section 2, page 2	We propose to continue operating the KSU TRIGA as we have done since 1962. The KSU TRIGA has a nearly 40 year history of safe and reliable operations….In 1968, authorization was given by the Atomic Energy Commission to increase the maximum steady-state thermal power to 250 kW and to permit pulsing the reactor to a peak thermal power of approximately 250 MW ($2.00 reactivity insertion). With the application to extend the operating license beyond the initial 40 years, authorization is sought to increase the maximum steady-state thermal power to 1,250 kW and to permit pulsing the reactor to a peak thermal power of approximately 1400 MW ($3.00 reactivity insertion).	Changed references to reactor from various terms to "KSU TRIGA"; rewrote reactivity from XXX$ to $XXX; changed to reflect new power level
Section 3, page 3	The KSU TRIGA is operated solely for educational and research purposes which benefit the community, the country and the environment. Specific benefits include:	Changed references to reactor from various terms to "KSU TRIGA"
Section 3.1.1, paragraph 2, page 3	…On top of this foundation, the KSU TRIGA serves as a training site for the mechanical and nuclear engineering students. At the KSU TRIGA the students gain practical experience in reactor operations, reactor safety, environmental concerns, health physics and interactive decision-making.	Changed references to reactor from various terms to "KSU TRIGA"
Section 3.1.2, paragraph 1, page 3	Many of the nuclear engineering graduates from Kansas State University enter professional careers in health physics and medical physics, with the Kansas State University Research Reactor providing an essential component to their education…	Rewording for clarity
Section 3.1.3, page 4	High school science classes use the KSU TRIGA for education and projects.	Changed references to reactor from various terms to "KSU TRIGA"
Section3.2, page 4	In addition to the educational programs, the KSU TRIGA and associated laboratories offer support of research programs not only within the university but also for educational and other public institutions throughout the country.	Changed references to reactor from various terms to "KSU TRIGA"
Section3.2.1, page 4	… Over the years, neutron activation analysis work performed for geologists around the country has constituted the bulk of the scientific support work at the KSU TRIGA reactor facility.	Changed references to reactor from various terms to "KSU TRIGA"
Section 4, page 6	Some low-level environmental risks cannot be eliminated. They include the use of nuclear fuel, the production of minimal gaseous effluents, the generation of some liquid and solid radioactive wastes, some waste heat, and some personnel radiation exposure.	Rewording for clarity
Section 4.1, pages 6-7	Major rewrite	RAI 1
Section 4.2, pages 7-8	Major rewrite	RAI 2 & RAI 3 (Para 3)
Section 4.3, pages 8-10	Major rewrite	RAI 4
Section 4.3, pages 8, paragraph 1	…There are no routine discharges related to reactor operation, and generation of radioactive material in this waste stream is independent of reactor operation.	RAI 5

Attachment I Revision to Proposed KSU Environmental Report		
SECTION	REVISION	REASON
Section 4.4, page 10	In practice, ^{41}Ar gas is the only gaseous radioactive effluent emitted from the reactor. The release rate is continuously monitored by a detector located within the effluent emission stack. Chapter 11, Appendix A of the Facility Safety Analysis Report shows that at full power continuous operations, the maximum off-site annual dose would be only 3.8 mrem (0.038 mSv), well within applicable limits. The KSU TRIGA staff routinely monitor for other potential effluent noble gases, halogens, or particulate matter. None have been detected in normal operations. During accident conditions, detection of gaseous releases would prompt reactor shutdown and secured ventilation.	Corrected reference to SAR; rewording for clarity; changed for new power level; changed references to reactor from various terms to "KSU TRIGA"
Section 4.5, pages 10-12	Major rewrite	RAI 6 (previously 4.5)
Section 4.6, pages 12-13	Major rewrite	RAI 7 & 8 (previously 4.6)
Section 4.6, page 12, paragraph 1 & 2	The KSU reactor core and beam ports are below grade. The experiment floor (0-foot level) is 12 ft below grade, with beam ports exiting biological shielding 30 in above the 0-foot level floor. It is not possible for personnel outside the reactor bay to have access to areas in line with three of the reactor beams. The 4th beam port exits in the direction of an adjacent equipment room; the room has visual surveillance at the entrance to the room form Ward Hall, and is equipped with electronic access controls. For all beam ports, the KSU Reactor Radiation Protection Program and facility procedures and instructions ensure that changes in experiment shielding are characterized and controlled to limit exposure to acceptable levels, including verification that the radiation levels in areas adjacent to the reactor bay boundary are either less than the levels required for a restricted area, or the areas are controlled as restricted areas.	RAI 8, part II
Section 4.7 pages 13-14	New sections	RAI 9
Section 5.2, page 15	The KSU TRIGA faculty and staff provides an open forum for the education about alternative energy sources. An informed public can make informed decisions. Because of the KSU TRIGA,...	Changed references to reactor from various terms to "KSU TRIGA"
Section 7, page 17	The short term use of the KSU TRIGA centers around the education of nuclear engineers, health physicists, research scientists and the general education of the students and community about nuclear energy and radioisotopes. The long term contribution that the KSU TRIGA provides, comes from the many contributions to society made by graduate engineers and scientists to the country. Numerous novel ideas have been developed over the past thirty years by students and scientists at KSU TRIGA. Some of these ideas have turned into commercial products and successful businesses. The KSU TRIGA serves as radiation science incubator of ideas and products. These products and services have an intrinsic societal value. The continued operation of the KSU TRIGA is not an irreversible commitment. Changes in programs, extent of operations, and potential decommissioning are all equally possible at any time in the future.	Changed references to reactor from various terms to "KSU TRIGA"
Section 8, page 18	The KSU TRIGA is an important education facility. It is an integral part of the Kansas State University plan for education, research and service commitment. It is an essential tool to scientists across all disciplines. It has no significant adverse environmental impact. Radiation exposures to non-KSU TRIGA personnel are not significant when related to the variation in natural radiation in the same area. (also KSU TRIGA in three following paragraphs)	Changed references to reactor from various terms to "KSU TRIGA"; reworded for clarity
Section 9, page 19	At the end of its useful life, the KSU TRIGA site will be returned to general university use..... The long term effects on the environment from renewing the operating license for the KSU TRIGA are insignificant.	Changed references to reactor from various terms to "KSU TRIGA"

ENVIRONMENTAL REPORT

Kansas State University
TRIGA Mark II Nuclear Reactor Facility

License R-88
Docket 50-188

26 September 2005

Department of Mechanical and Nuclear Engineering
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Table of Contents

1. INTRODUCTION

This environmental report is prepared in accordance with 10 CFR 51 as part of the nuclear reactor license renewal at Kansas State University (KSU). The KSU TRIGA Mark II nuclear reactor (KSU TRIGA) is a light-water cooled and moderated reactor using uranium fuel. The reactor has been operated since 1968 at thermal power levels up to 250 kW, and an application has been made to increase the maximum power level to 1,250 kW. The reactor is housed in the KSU Reactor Facility located in Ward Hall on the main campus of Kansas State University in Manhattan, Kansas. A full description of the reactor is contained in the Facility Safety Analysis Report, License R-88, Docket 50-188. Faculty providing training and education for nuclear engineers and heath physicists, and research scientists specializing in nuclear science and other disciplines use the reactor extensively as an education, training and research tool.

There are no safety considerations dependent on the duration of operations at the K-State facility. Because of licensed power and operating history of the facility, there are no fuel burn up or material damage issues to be considered.

2. PROPOSED ACTIONS

We propose to continue operating the KSU TRIGA as we have done since 1962. The KSU TRIGA has a nearly 40 year history of safe and reliable operations. The reactor was initially licensed in 1962 to operate at steady thermal power levels up to 100 kW. In 1968, authorization was given by the Atomic Energy Commission to increase the maximum steady-state thermal power to 250 kW and to permit pulsing the reactor to a peak thermal power of approximately 250 MW ($2.00 reactivity insertion). With the application to extend the operating license beyond the initial 40 years, authorization is sought to increase the maximum steady-state thermal power to 1,250 kW and to permit pulsing the reactor to a peak thermal power of approximately 1400 MW ($3.00 reactivity insertion).

3. IMPACT OF THE PROPOSED ACTIONS ON THE ENVIRONMENT

The KSU TRIGA is operated solely for educational and research purposes which benefit the community, the country and the environment. Specific benefits include:

3.1 Nuclear Education

3.1.1 Nuclear Engineering

Nuclear engineering is the principle discipline concerned with the safe release, control, and utilization of all types of energy from nuclear sources. Energy is needed to meet the world's technological needs and to maintain a suitable standard of living. Nuclear reactors are used to produce radioisotopes for diagnosis and therapy of disease, to produce research radio chemicals, and to provide energy sources for medical devices such as pacemakers and for probes to outer space. The engineering of safe nuclear power sources is vital to the future growth of the world.

K-State had one of the seminal U.S. Nuclear Engineering departments, which evolved (along with the K-State Mechanical Engineering department) into the Department of Mechanical and Nuclear Engineering (MNE). MNE offers nuclear education under a formal Nuclear Option program. All MNE students, regardless of enrollment status in the Nuclear Option, are educated in a fundamental nuclear engineering course. Therefore, K-State has the largest population of undergraduate engineering students receiving nuclear education. One strength of the Department of Mechanical and Nuclear Engineering is the on-site nuclear reactor. The Kansas State Nuclear Engineering program builds upon the foundations of mathematics, physics, thermal hydraulics, material science, radiation protection, radiation transport, interaction of radiation with matter and applied computer science. On top of this foundation, the KSU TRIGA serves as a training site for the mechanical and nuclear engineering students. At the KSU TRIGA the students gain practical experience in reactor operations, reactor safety, environmental concerns, health physics and interactive decision-making.

3.1.2 Health Physics

Health physics is a professional discipline based upon the scientific knowledge of, and the practical means for, radiation protection. The objective of a health physicist is to protect people and the environment from unnecessary exposure to radiation. Thus, the basic tenets of radiation must be understood, radiation knowledge explored, practical problems evaluated, radiation effects established and risk measurements relative to effect derived and implemented.

Many of the nuclear engineering graduates from Kansas State University enter professional careers in health physics and medical physics, with the Kansas State University Research Reactor providing an essential component to their education. The reactor provides the student with hands on, real world laboratory experience. It is at the reactor where the health physicist or medical physicist of the future learns how to monitor accelerators or nuclear reactors for safety, how to communicate with regulatory agencies, how to implement emergency plans and how to monitor for environmental radiation.

3.1.3 Community

High school science classes use the KSU TRIGA for education and projects. The reactor is used by the Boy Scouts of America for earning the nuclear merit badge. Annual programs offered through the K-State Engineering office and the K-State Extension office use the reactor in education programs for high school students interested in science. Students and faculty at the reactor often participate in middle school or high school "career days" representing nuclear science. Extensive tours are given to elementary and secondary student groups as well as university students and civic groups. Members of the staff of the Reactor Facility are active participants in city and county emergency planning groups and frequently host emergency training, drills, and exercises. The Reactor Facility also hosts training programs for operating personnel at nuclear power plants in Kansas and Nebraska.

3.2 Support of Scientific Programs

In addition to the educational programs, the KSU TRIGA and associated laboratories offer support of research programs not only within the university but also for educational and other public institutions throughout the country.

3.2.1 Nuclear Research Programs

The K-State reactor is supported by associated facilities, including specially equipped laboratories for neutron activation analysis and neutron radiography. Extensive use of the reactor is made by researchers in the physical sciences as well as plant and animal sciences. Over the years, neutron activation analysis work performed for geologists around the country has constituted the bulk of the scientific support work at the KSU TRIGA reactor facility.

3.2.2 Indirect Nuclear Research Programs

The Reactor Facility is supported by the U.S. Department of Energy as a Reactor Sharing Facility. Among institutions making use of or supported by the Reactor Facility are universities, law enforcement organizations, and such national organizations as the National Transportation Safety Board and the Armed Forces Radiobiology Research Institute.

3.3 Education for Future Energy Needs

The availability of energy strongly affects standards of living and quality of life. The increase in energy consumption is driven by the world population growth and by the desire of people everywhere to have higher standards of living. In nations where there are adequate supplies of electrical energy, health care improves, more children receive education, work is more productive, pollution control is better, life spans are longer, and more people have hopes for a better life for their children in stark contrast to energy poor countries.

Nuclear energy is a vital part of the nation's energy future. Nuclear energy produces thermal power without the release of carbon dioxide. Current scientific information indicates a strong correlation between carbon dioxide concentration in the atmosphere and mean earth temperature. An increase of mean earth temperature could cause significant worldwide environmental changes. Similarly, research suggests sulfur dioxide emissions from fossil fuel plants contributes to acid rain, and particulate and nitrous oxide emissions pose health hazards. Controls for these pollutants are costly, so that revitalization of nuclear power is being encouraged from ecologic and economic imperatives.

The demand for nuclear graduates supporting research into new-generation plants, engineering and operating staff, and health physicists at current (2002) levels is not being met. As the nuclear industry becomes more active, it is essential that the education infrastructure expand to ensure an educated nuclear workforce. K-State is the only institution in the Great Plains with an active nuclear education program supported by a reactor.

4. UNAVOIDABLE ENVIRONMENTAL RISKS

Some low-level environmental risks cannot be eliminated. They include the use of nuclear fuel, the production of minimal gaseous effluents, the generation of some liquid and solid radioactive wastes, some waste heat, and some personnel radiation exposure. None of these are considered significant with respect to environmental impact although each is individually assessed. They are:

4.1 Nuclear Fuel Cycle

The KSU TRIGA is designed for nominally 85 TRIGA fuel elements closely packed in a cylindrical core approximately 23 cm in radius and 38 cm in depth. Each fuel element contains uranium enriched less than 20% ^{235}U in a $ZrH_{1.6}$ matrix. The 8.5 weight % fuel contains up to 39 grams of uranium. Burnup is determined by power level and operating history, but historically 250 kW operations has resulted in an average of approximately 1 MWD per year, depleting about 1 gram of ^{235}U annually. Therefore, with the proposed maximum steady state power level of 1,250 kW and operations consistent with historical trends, burnup is estimated to result in a loss of approximately 5 grams of ^{235}U annually.

The ***Safety Analysis Report for the Illinois Advanced TRIGA (1967)*** summarizes calculation and experience of General Atomics that correlates 1 MWD of burnup for TRIGA fuel with a reactivity loss of $0.02. The report also provides data indicating steady state operation at 1.25 MW results in xenon worth of approximately $0.46 at 4 hours (a reasonable minimum to support research and experiments), $1.18 at 8 hours (normal work day), and $3.26 at 40 hours (steady state). Fuel temperature during 1,250 kW operations will require approximately $2.85 of reactivity. Therefore, 4 hours of operation will require excess reactivity of $3.31, and 8 hours of operation will require excess reactivity of $4.01. The proposed maximum excess reactivity limit of $4.00 permits slightly less than 8 hours of operation for the initial core loading, decreasing to a level that permits 4 hours of operation in about 7 years. After 7 years, it will be necessary to replace fuel in order to support programs. Therefore, fuel element replacement adequate to compensate for burnup will be required over the new license period twice, and fuel removed will require storage at the facility until disposal.

Projected Burnup and Reactivity			
Year	^{235}U (g) Burned	δk ($) Lost	Excess δk ($)
1	5	$0.10	$3.90
2	10	$0.20	$3.80
3	15	$0.30	$3.70
4	20	$0.40	$3.60
5	25	$0.50	$3.50
6	30	$0.60	$3.40
7	35	$0.70	$3.30

KSU has a large quantity of useable fuel (fresh and lightly burned) in storage. Two fresh elements are instrumented elements, and will replace elements in use when the thermocouples fail (i.e., possibly unrelated to fuel burnup). One spent fuel pit contains an element that cannot be used, and three of the elements in pool are instrumented aluminum elements not likely to be used. Useful fuel inventory (excluding not-useful elements or elements not likely to be used) is capable of replacing 894 grams of ^{235}U (39.2% of the ^{235}U in the core), more than adequate to replace the quantity of ^{235}U expected to be depleted by burnup over the license period. Storage facilities include a new fuel storage vault, 10 spent fuel storage pits for dry storage, and 10 in-pool storage racks for wet-storage. Spent fuel storage pits are capable of holding up to 8 elements. Pool storage rack capacity is 6 elements; additional pool storage racks are available but not currently installed, and KSU has the capability for fabricating additional racks on demand. Therefore, spent fuel storage at KSU is adequate to accommodate anticipated needs.

Since the fuel is already present at the KSU facilities with storage and utilization adequately managed, the only impact of the power up-rate will be utilization of fresh fuel elements in storage, requiring ultimate disposal of the fuel as spent fuel.

4.2 Releases of Solid Radioactive Waste

The major portion of solid radioactive wastes includes clean-up resins from the demineralizer systems, filters used in treating water for the demineralizer system and disposal of liquid wastes, and filters from the HVAC system. Other solid radioactive wastes include absorbent paper, plastic gloves, spent samples, some contaminated laboratory apparatus, spent standards, etc.

The reactor pool is maintained at low chemical contamination by a demineralizer. The resin is exhausted every two to three years, with about 1.5 cu ft replaced. The resin is aggregated for disposal as solid radioactive waste until a significant quantity can be collected for disposal, and decays significantly during aggregation. The power up-rate will not increase the amount of resin to be disposed of as waste, but may result in increased specific activity. Based on historical values, in no case is total activity of any radionuclide expected to exceed 400 μCi for a shipment. Some routine maintenance activities result in radioactive waste. In particular, scheduled replacement of air handling unit filters, discharges of the reactor bay sump, and replacement of primary resin generate small quantities of solid radioactive waste. Filters used in the reactor bay air handling unit are usually observed to be contaminated on removal, but the decay is characteristic of radon daughter products. Occasionally, a filter shows evidence of a longer lived radioactive species, but the level is generally so low that material characterization is difficult; these filters are aggregated and disposed of as solid radioactive waste. There is no correlation between operating history and frequency or amount of contaminated filters. The power up-rate will not increase the frequency of filter replacements (which is a scheduled activity), and is not likely to increase the volume of filters disposed of as solid radioactive waste.

Activities using radioactive material at Kansas State University are conducted under a State of Kansas radioactive materials license; the KSU reactor is one source of radioisotopes and activated material supporting KSU research, teaching and experimental programs. The bulk of solid radioactive waste generated by the reactor during the conduct of research and experiments under the State license is held for decay, with a small quantity infrequently disposed of through incineration and/or burial. The power up-rate may provide higher radioactive material specific activities subject to decay, but otherwise do not affect the KSU radiation protection program.

The recent history of solid waste transfer from the Reactor Facility is as follows:

	Solid Radioactive Waste Transfer
1994	77 mCi ^{3}H, 64 mCi ^{60}Co, 80 mCi ^{90}Sr, and 24 mCi of mixed radionuclides
1995	One 55 gal drum of dry waste containing up to 55 μCi of ^{60}Co; 29 ventilation filters with no detectable activity; 4 ventilation filters with hot spots up to 3000 cpm above background (< 1 μCi)
1996-2005	None

Operations at a higher power level may increase specific activity of spent resin, but the volume of the resin is not affected. Operations at higher power levels will not affect the volume of radioactive waste from maintenance activities. Operations at a higher power level may increase specific activity at discharge of samples and material from the reactor, but no significant change is expected in the character and quantity of radioactive waste from material supplied by the reactor to KSU research and experimental programs. Therefore, the impact of the power up-rate on the volume, rate of production, or disposal of solid radioactive waste is insignificant.

4.3 Releases of Liquid Wastes

The reactor bay is equipped with floor drains connected to a reactor bay sump. Liquid radioactive wastes are disposed of by collection and discharge through the rector bay sump. Recently, the bulk shield tank was discharged directly to sewerage to support maintenance/repairs. Historically, a campus service water system failed and discharged a large volume of water into the reactor bay; the water was sampled and discharged from the reactor bay sump. Occasionally, maintenance or decontamination activities result in contaminated water, which is then discharged to the reactor bay sump. There are no routine discharges related to reactor operation, and generation of radioactive material in this waste stream is independent of reactor operation.

The principle contribution to liquid radioactive waste stream is the reactor bay air handling unit (HVAC). The HVAC unit dehumidifies reactor bay air when the system is in the air conditioning mode; the moisture is deposited in the reactor bay sump through a floor drain. When the level in the reactor bay sump is high (generally about 800 gallons), the water is sampled and analyzed for contaminants and (if radioactive contamination and other NPDES limits are met) discharged to campus sewage treatment system. The pattern of discharges as tabulated below clearly shows this waste stream to be related to season, with most discharges occurring when air conditioning mode is established.

Analysis has shown a few radioactive isotopes contaminate the water, including tritium, ^{137}Cs, and ^{60}Co. Decontamination activities related to material on the State license have created a small but persistent trace of ^{137}Cs contamination. Spills of resin into the sump during change out operations have introduced small quantities of ^{60}Co contamination. Tritium is generated in the reactor pool and the bulk shield tank during operations, and any water surface exposed to bay atmosphere is likely to adsorb some of the material.

Although there is no correlation between operating history and the level of tritium discharged, the most likely source of the tritium is neutron interactions in light water. In the limiting case, tritium contamination can be expected be no more than historical values multiplied by the ratio of 1,250 kW to 250 kW. Releases are generally seasonal, related to air-conditioning condensate. The history of liquid releases since 1995 is as follows.

Radioactive Material Release to Sewerage
10 Year History

Date	Volume Released m^3	Total Activity Released (uCi) Alpha	Beta (Tritium)	Gamma ^{137}Cs	^{60}Co
08/04/05	3.07	0.017	NDA	NDA	NDA
07/11/05	3.30	474	NDA	NDA	NDA
06/15/05	2.98	89	NDA	NDA	NDA
09/23/04	2.68	0.05	3.62	1.65	NDA
08/18/04	2.68	NDA	71.6	0.04	NDA
07/19/04	3.28	39.5	1.48	0.2	NDA
06/21/04	2.45	NDA	7.92	NDA	NDA
03/30/04	2.00	NDA	133	NDA	NDA
09/24/03	4.20	NDA	NDA	NDA	1.5
06/11/03	4.20	NDA	67	1.26	NDA
06/26/02	2.50	NDA	31.8	1.5	NDA
09/04/01	2.50	NDA	NDA	NDA	NDA
08/02/01	2.50	NDA	54.6	29.6	NDA
07/09/01	2.50	NDA	NDA	NDA	NDA
05/09/01	2.50	NDA	51.8	NDA	NDA
08/30/00	2.50	NDA	112	NDA	NDA
08/01/00	25.00[a]	NDA	560	NDA	NDA
07/14/00	2.50	NDA	NDA	NDA	NDA
06/29/00	2.50	NDA	57.1	NDA	NDA
06/10/00	2.50	NDA	132.7	NDA	NDA
05/10/00	2.50	NDA	36	NDA	NDA
08/11/99	2.50	NDA	95	NDA	NDA
07/06/99	2.50	NDA	65	0.0968	NDA
01/08/99	50.00[b]	NDA	NDA	NDA	NDA
08/26/98	2.50	NDA	138	0.25	NDA
07/27/98	25.00[a]	NDA	1650	NDA	NDA
07/21/98	2.50	NDA	515	0.57	NDA
06/26/98	2.50	NDA	221	0.67	NDA
10/16/97	2.68	NDA	321.2	NDA	NDA
08/08/97	0.23	NDA	57.27	NDA	NDA
05/27/97	0.70	NDA	NDA	NDA	NDA
12/05/96	3.30	NDA[b]	495	NDA	NDA
08/12/96	3.00	NDA	579	NDA	NDA
06/26/96	3.20	NDA	371.2	NDA	NDA
09/05/95	3.00	NDA	405	NDA	NDA
08/15/95	4.20	NDA	399	NDA	NDA

Note [a]: Drained bulk shield tank; [b]: HVAC piping rupture

The power up-rate will not affect the volume or rate of production of radioactive waste, and the tritium concentration will remain within limits for discharge, although levels at discharge may be higher than historical values.

4.4 Release of Radioactive Gases

In practice, ^{41}Ar gas is the only gaseous radioactive effluent emitted from the reactor. The release rate is continuously monitored by a detector located within the effluent emission stack. Chapter 11, Appendix A of the Facility Safety Analysis Report shows that at full power continuous operations, the maximum off-site annual dose would be only 3.8 mrem (0.038 mSv), well within applicable limits.

The KSU TRIGA staff routinely monitor for other potential effluent noble gases, halogens, or particulate matter. None have been detected in normal operations. During accident conditions, detection of gaseous releases would prompt reactor shutdown and secured ventilation.

4.5 Radiation Exposure of Personnel

Beginning in 2002, permanent personnel exposure monitoring at KSU was changed from thermo luminescent dosimetry to laser stimulated dosimetry. The minimum reliable dose for the new system is 1 mrem, a change from the previous system minimum reading of 15 mrem. Personnel participating in nuclear laboratory courses are routinely placed on permanent monitoring beginning in 2002. The number of nuclear option students has been increasing significantly, resulting in a large number of monitored individuals.

Radiation exposures to reactor users and the operating staff are very small. Radiation exposures during the most recent years studied were as follows:

	Numbers of persons in annual-dose categories			
Year	Immeasurable[a]	< 0.1 rem	0.1-0.5 rem	> 0.5 rem
2004	6	56	0	0
2003[a]	4	50	0	0
2002[b]	5	19	0	0
2001	18	4	1	0
2000	23	5	0	0
1999	24	1	0	0
1998	15	2	0	0
1997	24	1	0	0
1996	18	2	0	0
1995	28	1	0	0
1994	38	1	0	0
1993	38	0	0	0
1992	28	0	0	0
1991	23	0	0	0
1990	20	0	0	0
1989	19	1	0	0
1988	23	3	1	0

	Numbers of persons in annual-dose categories			
Year	Immeasurable[a]	< 0.1 rem	0.1-0.5 rem	> 0.5 rem
1987	23	0	0	0
1986	26	1	0	0
1985	31	8	0	0
1984	33	1	0	0
1983	29	2	0	0
1982	26	7	0	0
1981	11	23	0	0

NOTE [a]: New dosimetry capable of reliably reading to 1 mrem (previous minimum reading 15 mrem)
NOTE[b]: Initiated issuing permanent dosimetry to all persons taking nuclear laboratory classes

Since implementation of the new system, the number of persons with a measurable dose less than 100 mrem is increased over historical values. This does not necessarily represent an increase in personnel exposure, but reflects the lower minimum measurable level and increase in the scope of the monitoring program. To better define exposure as a basis for projecting increase associated with the proposed power level change, a different categorization scheme was adopted with the lowest dose category recording less than 15 mrem and greater than 1 mrem; this category would not have recorded a measurable dose prior to 2003. Data for the three years with the new system was compiled and analyzed below.

A categorization of data was made, based on how closely the dose is related to the reactor. Since a large fraction of those monitored have little or minor interactions with the reactor, reactor staff and students with reactor-based projects were grouped with the label "Reactor," with the remainder of the monitored population categorized as "Students" or "Faculty" as appropriate. The number of occurrences of doses in the specified range was tabulated and averaged so that the table represents a rounded average of individuals in the relevant categories meeting exposure criteria. In this categorization scheme, the Reactor group has an average of 6 people per year greater than 1 mrem and less than 15 mrem, and about 8 people per year with a dose in excess of 15 mrem and less than 100 mrem. There were no exposures greater than 100 mrem for the three year period.

Average Annual Exposure by Category		
Functional	Dose Category	
Category	1 mrem< Dose < 15 mrem	15 mrem < Dose < 100 mrem
Reactor	6	8
Students	21	4
Faculty	2	1
Total	29	13

The "Students" category will not be affected by the power up-rate. The "Faculty" category has some contact with radiation fields associated with the reactor, but very limited (the high reading in the Faculty category was achieved by an emeritus faculty who does not enter the reactor bay area).

In a worst-case assumption, doses in excess of 20 mrem that occurred during 250 kW operations would scale causing a change in dose category (i.e., correspond to a dose greater than 100 mrem) at 1,250 kW. An average of 8 annual exposures exceeded 20 mrem; none of the exposures exceeded 100 mrem. Therefore, conservatively 8 annual exposures might fall into the category 0.1 to 0.5 mrem.

It should be noted that control of exposure is coupled to radiological conditions, and not directly to reactor power; simplistically scaling for the power up-rate ignores controls that limit exposures. The KSU TRIGA Reactor Facility has an active "AS LOW AS REASONABLY ACHIEVABLE" (ALARA) policy in place. In essence, The Program attempts to achieve, through engineering controls and thorough planning, detailed procedures to minimize radiation exposures to as low as possible. The goal is no annual exposure in excess of 10% of occupational limits and 50% of public limits. Therefore, even if the radiological controls applicable to 250 kW are used for 1,250 kW operations, the ALARA goals will be met. In reality, application of radiological controls consistent with previous practice is likely to result in exposures very similar to historical values.

In an unrealistic scenario, the increase in reactor power will not affect personnel exposures to a level that requires action under the ALARA program; in a more realistic scenario, some minimal increase in personnel exposure for those working directly with the reactor may be likely, but the increase will be very modest. Therefore, extrapolating from the total database of annual doses using the current personnel monitoring system, KSU reactor ALARA goals will be met during 1,250 kW operations.

4.6 Environmental Radiation Exposure

The KSU reactor core and beam ports are below grade. The experiment floor (0-foot level) is 12 ft below grade, with beam ports exiting biological shielding 30 in above the 0-foot level floor. It is not possible for personnel outside the reactor bay to have access to areas in line with three of the reactor beams. The 4th beam port exits in the direction of an adjacent equipment room; the room has visual surveillance at the entrance to the room form Ward Hall, and is equipped with electronic access controls.

For all beam ports, the KSU Reactor Radiation Protection Program and facility procedures and instructions ensure that changes in experiment shielding are characterized and controlled to limit exposure to acceptable levels, including verification that the radiation levels in areas adjacent to the reactor bay boundary are either less than the levels required for a restricted area, or the areas are controlled as restricted areas.

Sources of environmental radiation exposure include leakage through the biological shielding, activated material in the primary coolant system, and scattered radiation from extracted beams. Environmental Radiation Exposures around the reactor (including the exterior walls of the reactor bay) are monitored both by KSU TRIGA and University health physics staff in accordance with the approved Kansas State University Reactor Radiation Protection Program. For the period 1988-1998, exposure rates at the site boundary (against the outer wall of the reactor bay) during full power operation averaged 0.03 ± 0.02 mR/hour, with background approximately 0.01 mR/hour. For the period

1999-2004, the average exposure rate at the exterior walls of the reactor bay during full power operations was 0.044 mR/hour.

With a 5-fold increase in maximum reactor power, exposure rates at the exterior walls of the reactor bay (within the fenced area) can be expected to increase to 0.22 mR/hour at full power, within the limits for an unrestricted area (although access to the fenced area is controlled. The rate of dose accumulation as a function of power over operating time is therefore 0.176 mrem MW^{-1} h^{-1} or 0.00733 MW^{-1} D^{-1}. The power generation required to achieve 100 mrem is 568 MW h, or 23.7 MWD. As noted in 4.1, expected burnup is 5 MWD per year, corresponding to 0.0367 mrem annual exposure. Therefore, the impact of the up-rate on environmental radiation exposure is insignificant.

4.7 Secondary Cooling

Heat generated in the reactor is passed via primary coolant loop through a plate type heat exchanger where the heat is transferred to a secondary loop. The secondary cooling loop rejects heat through a standard, commercially supplied forced draft cooling tower. The cooling tower discharge path is bounded by the reactor facility and Ward Hall on two sides, open to a grassy area on the others. Secondary water is chemically treated to minimize scale buildup in the heat exchanger and maintain low corrosion.

4.7.1 Heat

The heat rejection from the KSU reactor cooling tower is insignificant in contrast to the more than 1700 window air conditioners, 300 central air units, and 10 building chillers supporting habitability on campus. In addition, routine operation of the central steam plant (located near Ward Hall) and a large accelerator and gigawatt laser laboratory (about 250 feet from the reactor building) add heat to the KSU campus. The heat output of the cooling tower is insignificant compared to other campus sources.

4.7.2 Makeup Water

Since the secondary cooling system relies on air cooling to reject heat produced by the reactor to the environment, some water is lost to (minimally) drift and (principally) evaporation. Therefore, water is periodically required to be added to make up for losses. The rate of evaporation varies according to environmental conditions, and is compensated for (as needed) by initiating a timer that controls a potable water valve delivering 22.7 gpm. The timer is currently set for 3 minutes, adding 68 gallons about once per hour in the summer months when humidity is low and temperatures are relatively high. At higher power levels, it may be necessary to either add makeup water at 12 minute intervals or increase the timer setting. A timer setting of 15 minutes provides 340 gallons per hour, 5 times the current makeup at full power operations.

The cooling tower draft contains high humidity, which is quickly dissipated by environmental conditions. There is no impact on the environment from the increased water utilization.

4.7.3 Secondary Chemical Treatment

Recommendations for secondary water chemical treatment are provided by the cooling tower vendor, using current methodologies. As treatment techniques improve, it can be expected that the specific chemicals used in the cooling tower will change, but personnel safety and environmental issues are always considered. Cooling tower chemicals have low volatility, so that escape of chemicals from the secondary system is minimal. There is no impact to the environment from the chemical controls of the secondary system.

There is no measurable environmental impact associated with operation of the secondary cooling system.

5. ADDITIONAL ENVIRONMENTAL BENEFITS

5.1 Provision of short half life radioisotopes

The availability of a nuclear reactor on campus provides researchers the opportunity to use short half life radioisotopes unavailable to users that don't have access to an on campus reactor. For example, sodium-22 is a typical sodium isotope scientists use if they have to purchase the isotope from a commercial source. Sodium-22 has a half life of 2.26 years. As an alternative and because of the capabilities of an on-site nuclear reactor, sodium-24 may be used. Sodium-24 has a 15 hour half life. Thus potential problems with packaging, shipping or receiving sodium-22 from a commercial source are diminished. Furthermore, sodium-24 can be held for radioactive decay for one week when all the radioactivity has dissipated. In contrast, all materials contaminated with sodium-22 would require radioactive waste disposal in a permitted site

5.2 Public awareness of environmental energy alternatives

The KSU TRIGA faculty and staff provides an open forum for the education about alternative energy sources. An informed public can make informed decisions. Because of the KSU TRIGA, Kansas State University employs faculty and staff with an expertise in nuclear science. This expertise is used to advise on radiological safety and alternative energy sources and issues germane to the local community. Such issues include regulations, radiation safety and environmental control for other universities, colleges and schools, industry and resolution of legal issues regarding ionizing radiation.

6. ALTERNATIVES TO THE CONTINUED OPERATION OF THE REACTOR

There is no comparable alternative facility. If the reactor is not relicensed, the quality of education for nuclear engineers and health physicists will be diminished. Research projects will come to a halt. The forward progress of nuclear science technology will be decreased.

7. RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES AND LONG-TERM BENEFITS

The short term use of the KSU TRIGA centers around the education of nuclear engineers, health physicists, research scientists and the general education of the students and community about nuclear energy and radioisotopes.

The long term contribution that the KSU TRIGA provides, comes from the many contributions to society made by graduate engineers and scientists to the country. Numerous novel ideas have been developed over the past thirty years by students and scientists at KSU TRIGA. Some of these ideas have turned into commercial products and successful businesses. The KSU TRIGA serves as radiation science incubator of ideas and products. These products and services have an intrinsic societal value.

The continued operation of the KSU TRIGA is not an irreversible commitment. Changes in programs, extent of operations, and potential decommissioning are all equally possible at any time in the future.

8. ANALYSIS

The KSU TRIGA is an important education facility. It is an integral part of the Kansas State University plan for education, research and service commitment. It is an essential tool to scientists across all disciplines. It has no significant adverse environmental impact. Radiation exposures to non-KSU TRIGA personnel are not significant when related to the variation in natural radiation in the same area.

The KSU TRIGA is already in operation. New capitalization funds are not necessary. It is the most prudent use of taxpayers money to continue operation of the nuclear reactor. At this point in time, initial capital investment costs have been paid off. All technology, science, education and services rendered now are at minimal cost. Thus the resultant benefit/cost ratio is very high.

The KSU TRIGA provides numerous technological spin-off's of products and services to the community. Graduates of the Kansas State University program are making significant contributions to the resolution of societal energy development problems and contribute products and services for the community.

The KSU TRIGA is the type of reactor potentially best suited for the evaluation of a new type of irradiation therapy known as neutron capture therapy. This technology has the potential for treatment of certain types of brain tumors that heretofore resisted all other forms of therapy.

9. LONG TERM EFFECTS ON THE ENVIRONMENT

At the end of its useful life, the KSU TRIGA site will be returned to general university use. The small additional increase in fuel burn-up will not be a significant factor. When finished, the fuel rods will be sent to a DOE facility where the unspent uranium will be recovered and the radioactive byproducts recovered for commercial use or packaged and shipped for disposal through commercial radioactive waste disposal brokers.

The long term effects on the environment from renewing the operating license for the KSU TRIGA are insignificant.