United States Department of the Interior
GEOLOGICAL SURVEY
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May 5, 1993

IN REPLY REFER TO:

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: USGS TRIGA Reactor Facility
Docket No. 50-274, License R-113

Gentlemen:

This letter is to request an amendment to the technical specifications for the US Geological Survey TRIGA research reactor facility (GSTR). Specifically, this request is to clarify the types of TRIGA fuel elements that may be used in the core by specifying that the fuel elements may have nominal uranium loadings from 8.5 weight percent (w%) to 12 w%. The enrichment restriction of less than 20% will not be changed. Steady state and pulsing power limitations will not be changed and our manner of operating the facility will not be changed.

Our current facility license and technical specifications require that the reactor core be an assembly of TRIGA Mark III stainless steel clad fuel-moderator elements. At the time of the reactor construction, TRIGA fuel elements had uranium loadings of 8.5 w%. The USGS safety analyses were based on use of these fuel elements. Since the late 1970's, General Atomics (GA) has developed new stainless steel clad fuel-moderator elements that have uranium loadings up to 45 w%, all of $\leq$20% enrichment. Currently, GA offers TRIGA fuel elements to commercial customers with uranium loadings up to 30 w%. There are both operational and economic advantages to the use of the higher loaded fuel assemblies. The increased uranium will give longer fuel element life and significantly lower

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fuel costs for the facility. This results in less fuel handling operations, a reduced probability of fuel handling accidents and reduced staff radiation exposure.

The safety analysis for this amendment request is enclosed along with the proposed wording for the amended Technical Specifications. This request is made in accordance with the provisions of 10 CFR 50.90.

If you have questions concerning this request, please contact Tim DeBey, the Reactor Supervisor, at (303) 236-4726.

Sincerely,

Carl Hedge

Carl Hedge
Reactor Administrator

Copies to:
U.S. Nuclear Regulatory Commission
Mr. L.J. Callan, Region IV

Tim DeBey, MS 974

SAFETY ANALYSIS

A number of research reactor facilities have experience with the higher uranium-loaded TRIGA fuel and cores with mixed element loading, including facilities at the University of Illinois, Michigan State University, Pennsylvania State University, the Armed Forces Radiobiology Research Institute, Aerotest Operations, and General Atomics. Two of these facilities operate at 1.5 MW steady state, 50% higher than the GSTR. No problems have been noted with the higher uranium loaded fuel at these facilities.

NRC report NUREG-1282 compares the properties and performance of TRIGA higher weight percent (w%) fuels with the 8.5 w% fuel.[1] The study evaluated fuels up to 45 w% uranium and considered neutron physics, materials properties, irradiation performance, fission product release, pulse heating and the limiting design basis. The report concluded that the performance of uranium-zirconium hydride fuel is substantially independent of uranium content up to 45 w% uranium. It also reported that the behavior of fuel with up to 30 w% uranium is indistinguishable from the 8.5 w% uranium fuel. The NRC staff also concluded that the low enrichment TRIGA fuel up to 30 w% uranium is generically acceptable for use in other licensed TRIGA reactors with the provision that case-by-case analyses discuss individual reactor operating conditions at those facilities.

GSTR FUEL ELEMENT POWER DENSITY

The GSTR is currently operating with 124 fuel elements in the core. This includes 3 fueled-follower control rods. At the rated power level of 1000 kW, this gives an average power density of 8.06 kW per element. Information from GA indicates that TRIGA fuel reaches the onset of film boiling (reduced heat transfer) at a power density of 43 kW per element. GA also reports a maximum radial peaking factor of 1.75 and a maximum axial peaking factor of 1.25 for TRIGA cores using 20 w% fuel.[2] For 8.5 w% fuel, the radial peaking factor is 1.45 while the axial peaking does not change. TRIGA 12 w% fuel would have a radial peaking factor of

1.55 and an axial peaking factor of 1.25. Therefore, the maximum power density for any element in the 8.5 w% GSTR core is 14.6 kW per element. The 12 w% fuel gives a 41% increase in uranium loading and a resultant increase in power generation per element. This increase in power density will be less than 41% due to self-shielding effects caused by the higher uranium loading, and a 35% increase has been calculated by Penn State University.[3] This gives a maximum power density of 20 kw per element for a 12 w% fuel element in the GSTR core. This value is more than 50% below that level required to start film boiling.

The original core of the GSTR contained 78 new 8.5 w% elements. A core made entirely of new 12 w% fuel elements is estimated to require 60 elements. This core would have a worst case peak power density of 32.3 kw per element at full power. This is still more than 25% below the level required to start film boiling. We do not intend to replace all existing fuel elements at one time with 12 w% fuel, but to replace high burnup elements with 12 w% fuel as needed to maintain our desired excess reactivity. Therefore, the actual power densities will be below the limiting cases given above.

FUEL TEMPERATURE

Fuel-moderator temperature is the basic limit of TRIGA reactor operation. The GSTR technical specifications require that midplane fuel temperatures be measured in the B or C ring elements during pulsing operations and that this measured fuel temperature not exceed 800 C. Past pulsing experience at the GSTR shows an expected measured fuel temperature of about 465 C from the maximum $3.00 pulses. A 35% increase in power density would give a measured fuel temperature in a 12 w% element of approximately 619 C for a $3.00 pulse. This is well below the 800 C limit. Actual measured temperatures are expected to be less since the peak temperature occurs closer to the cladding in the 12 w% fuel than in the 8.5 w% fuel. Penn State data for $3.00 pulses showed peak measured temperatures of about 520 C.[3] GA data show that the clad integrity of TRIGA fuel has been demonstrated for pulsing at fuel temperatures ≥1150 C.[4]

Steady state fuel temperatures are lower, with operational experience showing that the measured fuel temperature has been 325 C or less when operating at 1 MW. A 35% increase in power density would give a fuel temperature in a 12 w% element of approximately 430 C. Experience at the Penn State facility with 12 w% fuel showed 1 MW fuel temperatures near 450 C. GA has determined that an operational design basis temperature limit of 750 C will result in insignificant fuel growth and deformation. The calculated steady state fuel temperature for the GSTR with 12 w% fuel is more than 300 C below this limit.

FISSION PRODUCT RELEASE

GA has experimentally determined that a fission product release fraction of 1.5×10^{-5} is applicable for all conditions when the fuel temperature is $\leq$350 C. The release fraction rises to about 3.4×10^{-5} for a fuel temperature of 430 C. These release fractions are conservative since they assume that the reactor was operated continuously over a long period such that all fission products are at equilibrium activity.[4]

The following table gives a list of the important gaseous fission products that are produced in the GSTR. A 120 element core is assumed. The activity in a 12 w% element is given, with the assumption that the fission product inventory in that element is 2.6 times the average inventory per element. This increase is from worst case assumptions about axial and radial peaking (1.25 and 1.55 respectively), with the 12 w% fuel in the worst case location. The reactor room airborne activity concentrations (in uCi/ml) are calculated using a release fraction of 3.4×10^{-5}, a reactor room volume of 3.48×10^{8} cc and assuming complete mixing with no dilution from the ventilation system. These concentration values represent maximum possible levels in the reactor room.

Isotope	Fission Yield %	Half-life	Activity (Ci) in Core	Activity (Ci) in Element	Reactor room conc
Kr-83m	0.544	1.86 h	4560	99	9.5 e-6
Kr-85m	1.01	4.48 h	8460	184	1.8 e-5
Kr-85	0.293	10.5 y	1020	23	2.2 e-6
Kr-87	2.76	76 min	23120	501	4.9 e-5
Kr-88	4.38	2.84 h	36700	796	7.8 e-5
Kr-89	5.47	3.15 min	45830	993	9.5 e-5
Kr-90	5.00	32.3 s	41890	907	8.7 e-5
Xe-133m	0.16	2.19 d	907	20	1.9 e-6
Xe-133	6.62	5.25 d	29370	636	6.2 e-5
Xe-135m	1.83	15.3 min	15330	332	3.2 e-5
Xe-135	6.3	9.09 h	52530	1138	1.1 e-4
Xe-137	6.17	3.86 min	51700	1120	1.1 e-4
Xe-138	5.49	14.2 min	46000	997	9.5 e-5
Br-83	0.51	2.4 h	4270	93	8.7 e-6
Br-84	0.019	6.0 min	160	3.5	3.4 e-7
Br-85	1.1	2.87 min	9220	200	2.0 e-5
I-131	3.1	8.04 d	12740	276	2.7 e-5
I-132	4.38	2.29 h	36700	796	7.8 e-5
I-133	6.9	20.8 h	52390	1135	1.1 e-4
I-134	7.8	52.6 min	65350	1416	1.4 e-4
I-135	6.1	6.585 h	51080	1107	1.0 e-4

The airborne fission product concentration will decrease rapidly from decay and dilution. The reactor room emergency ventilation system gives an effective decay constant of 2.2×10^{-2} per minute. The reactor room concentration for any given gaseous fission product will be a factor of both the radioactive decay and the ventilation dilution. The following table gives reactor room concentrations (in uCi/ml) at increasing times following a worst case fuel element rupture.

Isotope	Reactor room airborne fission product activity (uCi/ml) 5 min	30 min	1 hr	8 hr	24 hr
Kr-83m	8.3 e-6	4.1 e-6	1.7 e-6	1.2 e-11	2.2 e-23
Kr-85m	1.6 e-5	8.7 e-6	4.2 e-6	1.4 e-10	7.7 e-21
Kr-85	1.9 e-6	1.1 e-6	5.8 e-7	5.6 e-11	3.8 e-20
Kr-87	4.2 e-5	1.9 e-5	7.5 e-6	1.6 e-11	1.6 e-24
Kr-88	6.8 e-5	3.6 e-5	1.6 e-5	2.9 e-10	3.9 e-21
Kr-89	2.9 e-5	6.7 e-8	4.7 e-11	0	0
Kr-90	1.4 e-7	1.7 e-21	3.4 e-38	0	0
Xe-133m	1.7 e-6	9.5 e-7	5.0 e-7	4.4 e-11	2.4 e-20
Xe-133	5.5 e-5	3.2 e-5	1.6 e-5	1.6 e-9	9.5 e-19
Xe-135m	2.3 e-5	4.2 e-6	5.6 e-7	3.0 e-19	0
Xe-135	1.0 e-4	5.6 e-5	3.0 e-5	1.3 e-9	3.1 e-19
Xe-137	4.1 e-5	2.7 e-7	6.3 e-10	0	0
Xe-138	6.7 e-5	1.1 e-5	1.4 e-6	1.6 e-19	0
Br-83	7.5 e-6	3.9 e-6	1.7 e-6	2.3 e-11	1.5 e-22
Br-84	1.7 e-7	5.5 e-9	8.7 e-11	7.4 e-36	0
Br-85	5.4 e-6	7.4 e-9	2.7 e-12	0	0
I-131	2.4 e-5	1.4 e-5	7.2 e-6	6.8 e-10	4.3 e-19
I-132	6.8 e-5	3.5 e-5	1.6 e-5	1.8 e-10	9.5 e-22
I-133	1.0 e-4	5.7 e-5	2.9 e-5	2.3 e-9	8.7 e-19
I-134	1.1 e-4	4.9 e-5	1.6 e-5	6.4 e-12	1.4 e-26
I-135	9.5 e-5	5.1 e-5	2.5 e-5	1.1 e-9	1.5 e-19

At one hour after the release, most of the isotopic airborne concentrations in the reactor room are below the occupational limits for airborne activity, and after six hours the reactor room would no longer be an airborne radioactivity area.

Data were used from Reg. Guide 1.109 and Appendix B of the revised 10 CFR 20 to calculate radiation doses from both submersion and inhalation of the released fission products. Calculations were performed for a one hour stay time and a six hour stay time. Exposures beyond six hours after the fuel cladding failure would be

insignificant. Occupational doses are calculated for a person in the reactor room during the fuel failure and public doses are calculated for a person standing outside the reactor facility, at the point of nearest public access. The results are given below.

	Occupational doses (mrem)		Public doses (mrem)	
Isotope	1 hour stay	6 hour stay	1 hour stay	6 hour stay
Kr-83m	<0.1	<0.1	<0.1	<0.1
Kr-85m	1.2	1.5	<0.1	<0.1
Kr-85	<0.1	<0.1	<0.1	<0.1
Kr-87	10.8	12.6	<0.1	<0.1
Kr-88	49	60	0.2	0.3
Kr-89	49	49	0.3	0.3
Kr-90	4	4	<0.1	<0.1
Xe-133m	<0.1	<0.1	<0.1	<0.1
Xe-133	0.9	1.1	<0.1	<0.1
Xe-135m	2.1	2.1	<0.1	<0.1
Xe-135	15.0	19.1	<0.1	<0.1
Xe-137	60	60	0.3	0.3
Xe-138	13.3	13.5	<0.1	<0.1
Br-83	0.4	0.5	<0.1	<0.1
Br-84	<0.1	<0.1	<0.1	<0.1
Br-85	<0.1	<0.1	<0.1	<0.1
I-131	1842	2444	3.2	4.3
(thyroid)	17874	24349	127	172
I-132	31.7	38.6	0.1	0.1
(thyroid)	289	361	2.1	2.6
I-133	1525	2005	2.5	3.3
(thyroid)	12348	16645	88	118
I-134	7.1	7.9	0.1	0.1
(thyroid)	69	79	0.5	0.5
I-135	196	251	0.3	0.5
(thyroid)	1662	2188	11.8	15.5

TOTAL DOSE (mrem)						
	Occupational			Public		
	1 hour stay	6 hour stay	Annual CFR Limit	1 hour stay	6 hour stay	Annual CFR Limit
Whole Body	3807	4970	5000	7.0	9.2	100
(thyroid)	32242	43622	50000	229.4	308.6	~3000

The conditions required to achieve the doses in the previous table are: (1) worst case loading of a 12 w% fuel element to achieve maximum flux peaking, (2)a 12 w% element with essentially no fission product poisons (no burnup), (3) reactor operated continuously at full power for at least 40 days, 24 hours a day, (4) the 12 w% element removed from the reactor tank immediately after shutdown, (5) a large cladding failure occurs in the element immediately after being removed from the water, and (6) personnel inside and outside the facility ignore alarms and procedures, staying in areas of highest airborne radioactivity for extended periods of time.

The worst case fission product release analysis shows that the CFR limits for occupational exposure could not be exceeded under the above conditions even if the reactor room was continuously occupied for several hours following the accident. In no case would the public be exposed to levels exceeding the CFR limits. The simultaneous occurrence of these conditions is not considered credible, but represents a worst case scenario.

In summary, historical experience at other research reactor facilities has shown that cores fueled with both 8.5 w% and 12 w% TRIGA fuel can be operated safely in both steady state and pulsing reactors. Past analyses show that the TRIGA fuel behaves essentially the same with the two different uranium loadings. Facility specific analyses for the GSTR show that it is not credible for a cladding rupture to cause personnel to receive radiation doses above the dose limitations of 10CFR20.

The proposed GSTR Technical Specification change is given below as a revised Section D.1, p 4.

CURRENT WORDING:

D. Reactor Core

1. The core shall be an assembly of TRIGA Mark III stainless steel clad fuel-moderator elements arranged in a close-packed array except for (1) replacement of single individual elements with incore irradiation facilities or control rods; (2) two separated experiment positions in the D through E rings, each occupying a maximum of three fuel element positions. The reflector (excluding experiments and experimental facilities) shall be water or a combination of graphite and water.

PROPOSED WORDING FOR AMENDMENT:

D. Reactor Core

1. The core shall be an assembly of TRIGA stainless steel clad fuel-moderator elements, nominally 8.5 to 12 w% uranium, arranged in a close-packed array except for (1) replacement of single individual elements with incore irradiation facilities or control rods; (2) two separated experiment positions in the D through E rings, each occupying a maximum of three fuel element positions. The reflector (excluding experiments and experimental facilities) shall be water or a combination of graphite and water.

The next page is a replacement page for the GSTR Technical Specifications.

2. The pool water shall be sampled for conductivity at least weekly. Conductivity averaged over a month shall not exceed 5 micromhos per cm^2. This item is not applicable if the reactor is completely defueled and the pool level is below the water treatment system intake.

D. <u>Reactor Core</u>

1. The core shall be an assembly of TRIGA stainless steel clad fuel-moderator elements, nominally 8.5 to 12 w% uranium, arranged in a close-packed array except for (1) replacement of single individual elements with incore irradiation facilities or control rods; (2) two separated experiment positions in the D through E rings, each occupying a maximum of three fuel element positions. The reflector (excluding experiments and experimental facilities) shall be water or a combination of graphite and water.
2. The excess reactivity above cold critical, without xenon, shall not exceed 4.9% delta k/k with experiments in place.
3. Fuel temperatures near the core midplane in either the B or C ring of elements shall be continuously recorded during the pulse mode of operation using a standard thermocouple fuel element. The reactor shall not be operated in a manner which would cause the measured fuel temperature to exceed 800^{o}C.
4 Power levels during pulse mode operation that exceed 2500 megawatts shall be cause for the reactor to the shut down pending an investigation by the reactor supervisor to determine the reason

REFERENCES

1. NUREG-1282 "Safety Evaluation Report on High-Uranium Content, Low-Enriched Uranium-Zirconium Hydride Fuels for TRIGA Reactors" U.S. Nuclear Regulatory Commission, 1987.

2. Personal communication with General Atomics personnel, 1993.

3. Safety Evaluation for the Penn State Breazeale Reactor use of 12 w% fuel. Pennsylvania State University, (no date).

4. "The U-ZrH_x Alloy: Its Properties and Use In TRIGA Fuel", General Atomics E-117-833, 1980.