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September 12, 1986

Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Document Control Desk

REFERENCE: Docket 50-186
University of Missouri

SUBJECT: Change to University of Missouri Research Reactor Facility License No. R-103

Gentlemen:

The University of Missouri has designed a new aluminide UAl_x fuel element to significantly reduce the fuel cycle cost and reduce the amount of U-235 needed per MWD of energy produced. The element can be safely used at 10 MW with our current fuel elements. This submittal will describe the new element, give the technical bases, and request revisions to technical specifications to base them on the technical limits instead of the values for a specific fuel element loading.

The new fuel element will have the same appearance and dimensions as our current fuel element (figure 1). The only changes are the uranium loaded per fuel plate and boron carbide included as a burnable poison in selected plates. The amount of uranium (U-235) and boron loaded per plate are given for the present and new fuel elements in table 1. Our present element (775) has all the fuel plates loaded to a uniform 1.55 grams uranium (93% enriched in U-235) per cubic centimeter (cm^3) of fuel meat. The increase in grams per plate for the 775 element is due to the size of the plates increasing from plate 1 to plate 24. The density of uranium in the new element (1270) fuel meat decreases from plate 8 to plate 1 and from plate 19 to plate 24. Fuel plates 8 through 19 are loaded uniformly at 3.0 grams uranium (93% enriched in U-235) per cm^3. Both fuel elements are made from aluminide UAl_x fuel clad with aluminum. The 775 element is made from UAl_x that is mostly in the UAl_3 phase while the 1270 element UAl_x is mostly in the UAl_2 phase. Table 2 compares the significant differences between the two elements. Enclosure A is the specification for fabrication of the University of Missouri 775 gram U-235 fuel element. Three changes are required to this specification for fabrication to cover the new fuel element. In paragraph 3.4.2(1) on page 14, the 775 gram loading will be changed to 1270 grams. The U-235 and boron loadings given in table 1 of this submittal will replace the values given in the table on page 24. UAl_2 will replace UAl_3 in paragraph 3.3.2 on page III-4.

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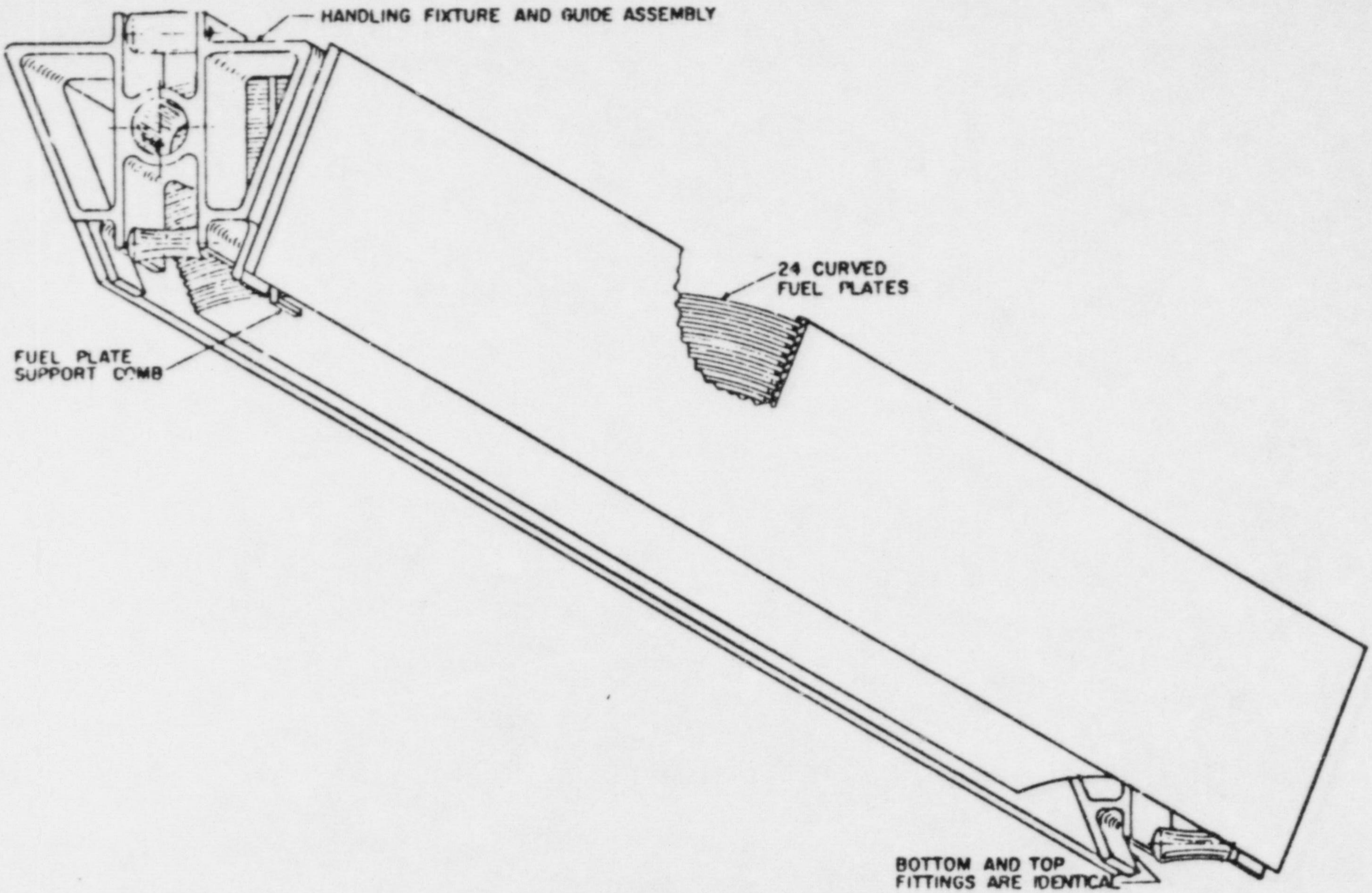

Figure 1

MURR Fuel Element

Table 1

Uranium and Boron Loading

for 775 and 1270 Gm Elements

	Present Element	New Element	
Plate Number	U-235 Content(gm)*	U-235 Content(gm)*	Boron Content (Natural)
1	19.26	11.38	.080
2	20.39	15.11	.085
3	21.53	19.13	.088
4	22.66	28.12	.091
5	23.79	34.25	.095
6	24.93	43.15	
7	26.06	50.83	
8	27.19	53.06	
9	28.33	55.30	
10	29.46	57.54	
11	30.59	59.78	
12	31.73	62.02	
13	32.86	64.26	
14	33.99	66.52	
15	35.12	68.76	
16	36.26	70.99	
17	37.39	73.23	
18	38.52	75.47	
19	39.66	77.71	
20	40.79	75.82	
21	41.92	67.55	.155
22	43.06	57.08	.159
23	44.19	47.09	.163
24	45.32	36.22	.166
	775 grams	1,270.37 grams	1.082 grams

* ± 1.0% per plate

Table 2

Summary Sheet

Comparing Fuel Elements

	Existing 6.2 Kg Core	Proposed 10.16 Kg Core
Fuel Content (grams U-235/element)	775	1270
Type of Fuel	Aluminide-UAl_x mostly UAl_3 Phase	Aluminide-UAl_x mostly UAl_2 Phase
Grams U-235 Loaded Per Cubic Centimeter	1.5 - 1.6	0.9 - 3.0
Boron Content (grams Natural Boron/Element)	Trace Impurities	1.08
K_{eff} (clean core - rods full out)	1.079	1.061
Control Blade Worth (ΔK)	0.165	0.153
Peak Burnup Density (Fissions/cm^3 of fuel meat)	$< 1.8 \times 10^{21}$	$< 2.3 \times 10^{21}$
Energy per Element at Peak Fission Density (MWD/element)	≈ 150	≈ 300

TECHNICAL BASIS

The excellent performance of aluminide UAl_x fuels has been consistently demonstrated for the past fifteen years in test and research reactors such as the Advanced Test Reactor (ATR) and MURR. MURR has used over 300 UAl_x fuel elements since August 1971 with no failures or detectable leaking fuel elements. ATR has used more than 2000 UAl_x fuel elements since 1972 and has 20 on hold as possible leaking fuel elements. All ATR leaking elements have been caused by pitting corrosion. ATR has had no other type of UAl_x fuel element failure and no failures at all during the past five years.

All of the ATR and MURR aluminide fuel has been made from UAl_x powder that is primarily in the UAl_3 phase before the fuel fabrication compacting step. However, the Extended Life Aluminide Fuel (ELAF) program[1] demonstrated that fuel plates made with UAl_x powder primarily in the UAl_2 phase, performed as well, or better, than fuel plates made from primarily UAl_3 phase powder. The ELAF program was conducted for the Department of Energy, the University of Missouri (UM), and the Massachusetts Institute of Technology (MIT). The ELAF program was initiated in 1980 with the objective of demonstrating that fuel loading and burnup limits for fuel elements in a university research reactor could safely be increased beyond the license limits for the MURR and MIT research reactors. Thirty plates were run in the ATR reflector lobes in various combinations of 12 at a time during July 1981 to June 1985. The post irradiation examinations (P.I.E.) were completed in May 1986 and documented in the Extended Life Aluminide Fuel Final Report (EGG-2441; June 1986) - enclosure B.

MAXIMUM BURNUP LEVELS

The aluminide fuels loaded up to 50 vol % UAl_x are capable of burnups greater than 2.3×10^{21} fissions per cm^3 of fuel meat. This has been demonstrated by the over two thousand fuel elements used to this level in the ATR reactor. Additionally, the ELAF program concluded that 50 vol % UAl_2 composition plates performed as well or better than the 50 vol % UAl_3 composition plates. Burnups to this level result in less than 10% swelling of the fuel plates. It has been found that fuel plate swelling of less than 10% has no detrimental effect on fuel plate performance. Therefore the limiting conditions of operation on peak burnup can safely be set at 2.3×10^{21} fissions per cm^3 based on the many years of experience ATR has had using this burnup limit with no failures due to loss of fuel meat integrity. MURR's present burnup limited is 150 MWD per element which corresponds to between 1.7 to 1.8×10^{21} fissions per cm^3. There have been no aluminide fuel element failures at MURR.

THERMAL POWER DENSITY

The MURR safety limits were derived in 1973 and are based on a nuclear peaking factor of 3.678 which corresponds to a peak power density of 1114 watts per cm^3 of core region. This does not include the engineering peaking factors. This peaking factor was based on a mixed core loading of fresh and depleted (1.8×10^3 fissions per cm^3) 775 fuel elements. The peaking factor was determined using a two dimensional neutron diffusion code - EXTERMINATOR-II, which does not have fuel depletion capability. To analyze the power densities for the various combinations of new and current fuel elements, the BOLD VENTURE-IV and AMPX-II code systems were obtained from the Radiation Shielding Information Center at Oak Ridge National Laboratory. The BOLD VENTURE-IV code system can perform three dimensional nucleonics analysis including fuel depletion using diffusion theory. The code systems and MURR computer models were benchmarked against the results of a destructive analysis of a 775 fuel element with 82.5 MWD power history and gave excellent agreement as shown in enclosure C. After benchmarking the code system and model, possible core loadings of fresh and depleted (2.3×10^{21} fissions per cm^3) 775 and 1270 fuel elements were modeled to determine which would have the highest power density. The highest power density was in a core of four fresh 775 elements and four depleted 1270 elements. The nuclear power peaking factor was 3.225 which corresponds to a maximum power density of 977 watts per cm^3. The 1270 elements were modeled with the 1.08 grams of boron included, and the control rod height was set at 13 inches withdrawn. The maximum power density occurs on the first plate of the fresh 775 element and increases as the control rods are inserted. Because the control rods are below the estimated critical position of a core of four fresh 775 and four depleted 1270 containing no boron, the model has a greater radial and axial power peaking. With the boron in the model, the power density is a little lower in the 1270 plate 1 causing the peaking factor for the 775 plate 1 to be slightly higher due to the higher azimuthal peaking factor. Therefore the analysis covers the worst case peaking for any range of boron loadings in the new fuel elements from 0.00 to 1.08 grams per element. The next highest power peaking factor was 3.146 for four fresh 775 and four depleted 775; it corresponds to a maximum power density of 953 watts per cm^3. Therefore, the new 1270 and present 775 fuel elements can be used together at burnups up to 2.3×10^{21} fissions per cm^3 and operated with a greater margin from DNB and flow instability than that on which the safety limits are based.

GEOMETRY AND CORE CONFIGURATION

The new fuel element physical construction is identical to the present fuel element. The MURR core will not change and is designed to use eight fuel elements all with the same symmetry about the central flux trap. The new fuel element has a higher U-235 loading than the present element which results in a higher average power density in the new element when mixed cores of 775 and 1270 elements are used. But the variation in uranium density per plate makes the peak power density lower in a new element. Therefore, there are no significant geometry differences using the new 1270 fuel element.

THERMAL CHARACTERISTICS

With a lower nuclear peaking factor, the maximum fuel and surface temperatures are less in the new fuel than those assumed in the present fuel. In mixed core loading of 775 and 1270 elements, the highest peak occurs in the fresh 775 elements. The maximum fuel center line temperature is 303 degrees Fahrenheit with a clad surface temperature of 244 degrees Fahrenheit.

MANUFACTURING DATA

The new fuel will be made by the same process as the present fuel elements (enclosure A). The only changes will be higher UAl_x loading in most plates, burnable poisons in selected plates, and using UAl_2 phase UAl_x powder. The aluminide UAl_x fuel has proven to be a very safe and reliable fuel at ATR, MURR, MITR, and other research reactors. The ELAF program and Dienst[2] study show that the UAl_2 phase UAl_x performs as well as or better than the UAl_3 phase fuel.

FUEL DENSITY

Most of the 24 fuel plates in the new fuel element are loaded at a higher density of uranium than the present element. Plates 8 through 19 of the 1270 element will be loaded to 3.0 grams uranium per cm^3 versus the 1.55 grams per cm^3 for the 775 element. The fuel density decreases from plate 8 to plate 1 and from plate 19 to plate 24. The fuel density in these plates is roughly inversely proportional to the radial power peaking factor for the plate in the uniformly loaded element. Plates 1 through 3 and 24 correspond to a lower fuel density in the new element than in the present fuel element. With the variation in fuel density, the new fuel element operates with a more uniform power density. This results in a lower peak power level and fuel temperatures.

FAILURE HISTORY

The new fuel should have the same excellent performance record as the present fuel elements. MURR has used over 300 UAl_x fuel elements since 1972 with no detectable fuel failures. ATR has used over 2000 UAl_x fuel elements during the past ten years with no core failures. ATR has held back 20 elements as possible leaking elements due to pitting corrosion, but there has been no indication of new leaking elements in the past five years. The new fuel element will not make a significant change in the very low probability of fuel element failure.

FUEL SWELLING OR BLISTERING

There have been no detected blister problems on MURR and ATR aluminide fuel elements or the ELAF fuel plates. When the plates have been blister tested, the blisters do not start to occur until the plate temperature is above 800°F. The fuel does swell as a function of burnup. The correlations for swelling in the ELAF plates are given in the ELAF report and are in good agreement with correlations for swelling in aluminide fuels in previous studies.[2,3] The correlations show that the swelling is less than 10% in plate thickness for average burnups up to 2.8×10^{21} fissions per per cm^3. Therefore the swelling due to a peak burnup of 2.3×10^{21} fissions per cm^3 will cause no detrimental effect on fuel plate performance, even though it is an increase in the present peak burnup limit of 1.8×10^{21} fissions per cm^3. The present limit was based on the best experience available on UAl_x fuels when it was set in 1972. The over 2000 UAl_x fuel elements used for burnups of

2.3×10^{21} fissions per cm^3 at ATR during the past ten years without any dimensional stability problems show that the burnup limit can be easily increased without any problem. The only reason MURR has not previously requested this change is because the present fuel elements are reactivity limited when they reach the present burnup limit. The dimensional stability of the plates can be considered a function of specific power and temperature as well as the burnup. However, for a low pressure research reactor the stability does not have a strong dependence on power or temperature until these variables are well above the limits placed on them in the reactor core safety limit (technical specification 2.1) due to critical heat flux.

CORROSION BEHAVIOR

MURR has experienced no failures or problems with aluminide fuel due to corrosion, and the new aluminide fuel should perform as well. The ELAF report notes that three of the thirty fuel plates failed due to pitting corrosion, where a corrosion pit slowly developed through the cladding on the plate until a fission product leakage path was formed. This will not cause any safety problem for MURR using the new fuel elements for two reasons. First, this kind of failure is not catastrophic. A corrosion pit develops slowly and penetration of the cladding is easily detected due to our minimum detectable activity levels for most of the iodine fission products is approximately 1×10^{-7} µci/ml. Second, the corrosion rate of the new fuel in MURR is expected to be less than that experienced in the ELAF plates. The maximum pit corrosion rate equation in the ELAF report correlates well to the ELAF plates and ATR fuel elements - which all were run in the ATR primary coolant. Nitric acid is added to ATR primary coolant to maintain a pH in the coolant lower than that maintained in the MURR primary coolant. The difference in primary chemistry control could cause a difference in pit corrosion rate. Applying the maximum pit corrosion rate equation to the MURR fuel element cycle predicts that the maximum pit depth would have exceeded .015 inches (nominal clad thickness) for at least thirty fuel elements which have been used since 1972. However, no leaking UAl_x fuel elements have ever been detected at MURR. Therefore, no changes are required in water chemistry and surveillance specifications due to corrosion behavior.

DESIGN BASIS ACCIDENT AND ENVIRONMENTAL CONSIDERATIONS

The new fuel will cause no changes to the design basis accident (DBA) and environmental considerations. This is because there is no change in the operating power, operating schedule, type of fuel, core geometry, core hydraulics, or quantity and type of significant fission products. The fission products of interest in the DBA are the iodine nuclides. The concentration of fission products is a function of the power density, type of fissile fuel, and operating history on a fuel element. The new fuel element will only change the operating history per element - it will be in the core approximately twice as long as the present fuel elements. However, the longer operating history will not cause a significant change in the iodine concentrations, since the change is from a fuel element being in the core for a total of 120 days spread over a year to 240 days spread over two years. The significant iodine activites will be at equilibrium values before the first 120 days of operation has ended. Additionally, there will be no significant change in environmental consideration since the type and quantity of effluents released will not change due to the new fuel element.

REVISIONS TO TECHNICAL SPECIFICATIONS

The University of Missouri requests that the fuel related technical specifications for the University of Missouri Research Reactor (MURR) license R-103 be revised to cover the new fuel element design and extend the burnup limit for the present fuel element but be based on actual technical limits instead of being based on values for specific fuel element designs. This revision is consistent with the requirements of 10CFR50.36 (Technical Specifications). There are three fuel specific technical specifications (T.S.) that need to be revised to the actual technical limits: T.S. 3.8 - limiting condition of operation for fuel; T.S. 4.1 - fuel design features; and T. S. 5.5 - surveillance requirements for fuel.

Three of the five specifications in T.S. 3.8 need to be revised to base them on 10CFR50.36(c)(2) requirements -

> "Limiting conditions for operation are the lowest functional capability or performance levels of equipment required for safe operation of the facility . . . "

MURR requests T.S. 3.8.a,c, and d be changed to read as follows:

3.8.a: The peak burnup for UAl_x intermetallic fuel shall not exceed a calculated 2.3×10^{21} fissions per cubic centimeter.

3.8.c: The reactor core shall consist of eight fuel assemblies for which the associated power peaking results in a greater than or equal maximum allowable power than that given in figures 2.0, 2.1, 2.2 of specification 2.1 for the various combinations of core flow rate, reactor inlet temperature and pressurizer pressure. Exception: The reactor may be operated to 100 watts above shutdown power on less than eight assemblies or with greater power peaking for purpose of reactor calibration or multiplication studies.

3.8.d: All fuel elements or fueled devices outside the reactor core shall be stored in a geometry such that the calculated K_{eff} is less than 0.95 under all conditions of moderation.

Two of the three specifications in T.S. 4.1 need to be revised to base them on 10CFR50.36(c)(4) requirements:

> "Design features to be included are those features of the facility such as materials of construction and geometric arrangements, which, if altered, or modified, would have a significant effect on safety and are not covered in categories described in paragraphs (c) (1), (2), and (3) of this section."

MURR requests T.S. 4.1b and c be changed to read as follows:

4.1.b: The fuel meat shall be fully enriched uranium 235 aluminide UAl_x and the nominal composition of the powder used to make the fuel meat shall not exceed 50 volume % UAl_x powder.

4.1.c: The fuel meat may include Boron carbide loaded as a burnable poison. The Boron carbide shall not exceed 0.05 grams (B_4C) per cubic centimeter.

The specifications in T.S. 5.5 need to be revised to base them on 10CFR50.36(c)(3) requirements:

> "Surveillance requirements are requirements relating to test, calibration, or inspection to assure that the necessary quality of systems and components is maintained, that facility operation will be within the safety limits, and that the limiting conditions of operation will be met."

MURR requests T.S. 5.5.a and b be changed to one paragraph and to read as follows:

5.5: One fuel element from each consecutively numbered series of eight elements will be randomly selected and the fuel plates inspected for anomalies after a peak fuel element burnup corresponding to greater than 90 percent of the peak burnup limit (specification 3.8.a). If all of a series of eight elements are removed from use before they reach 90 percent of the peak burnup limit, then one of the four fuel elements with the higher average power histories will be inspected.

The following changes need to be made to the bases as stated in technical specifications:

3.8.a: The fuel burnup limit restricts the peak fissions per cm^3 burnup to values correlated to result in less than a 10% swelling of the fuel plates. It has been found that fuel plate swelling of less than 10% has no detrimental effect on fuel plate performance. (Ref. License R-103 Change No. 4 dated August 12, 1968, Change No. 6 dated November 25, 1970, and Amendment No. ___ dated September 12, 1986).

3.8.c: To assure the validity of the safety limit curves (specification 2.1) and other safety analysis, specification 3.8.c limits the core to eight fuel elements and their maximum power peaking for operation at any significant power level.

4.1: The fuel elements for the University of Missouri reactor are of a configuration (aluminide UAl_x plate type) successfully and extensively used for many years in test and research reactors. The specifications require fuel content and dimensions in accordance with design basis criteria for proper heat transfer and can be safely used to the burnup limits of Technical Specification 3.8.

Reference: (1) Hazards Summary Report, July 1965, Section 4.2

(2) Hazards Summary Report, July 1965, Section 5.5

(3) Letter, September 12, 1986, University of Missouri to Nuclear Regulatory Commission requesting amendment No. ___ to R-103 License.

The revised Technical Specification pages are in Appendix A.

The University believes that based upon the studies performed and past operating experience of research and test reactors using aluminide UAl_x fuel that this new fuel can be used in the University of Missouri Research Reactor without undue hazard to the health and safety of the public. If additional information is needed or desired, please call Charlie McKibben at 314-882-4211.

Respectfully submitted,

J. C. McKibben
J. C. McKibben
Director
Upgrade Project

Reviewed and Approved:

D. M. Alger
D. M. Alger
Associate Director
Research Reactor Facility

STATE OF MISSOURI)
)ss.
COUNTY OF BOONE)

On this 12th day of September, 1986, personally appeared before me, J. C. MCKIBBEN and D. M. ALGER, known to me to be the persons who executed the foregoing document.

Subscribed and sworn to before me, Sharon Vanlandingham, a notary public.

My commission expires: 2-21-87

Sharon Vanlandingham
Notary Public

Sharon Vanlandingham
Notary Public State of Missouri
My Commission Expires 2-21-87
County of Boone

Enclosure A - EG&G Idaho, Inc., Specification TRTR-4 for University of Missouri Fuel Elements, Assembled for MURR, May 2, 1986
B - EG&G Idaho, Inc., Extended Life Aluminide Fuel Final Report; EGG-2441, June 1986
C S. S. Kim and C. McKibben, MURR Upgrade Neutronics Analysis Using AMPX-II/Bold Venture IV Computation System Benchmarked to The Destructive Analysis of Fuel Element 775F3, MURR Internal Report, September 1, 1986

REFERENCES:
1. L. G. Miller and J. M. Beeston, Fuel Plate and Fusion Insulator Irradiation Test Program, EGG-FT-5273, November 1980.
2. W. Dienst, S. Nazare, and F. Thummler, "Irradiation Behavior of UAl_x-Al Dispersion Fuels for Thermal High Flux Reactors," Journal of Nuclear Material, 64, 1, 1977.
3. J. M. Beeston et al., "Development and Irradiation Performance of Uranium Aluminide Fuels In Test Reactors," Nuclear Technology, 49, June 1980, pp. 136-149.