50-274

# United States Department of the Interior

GEOLOGICAL SURVEY
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DENVER FEDERAL CENTER
DENVER, COLORADO 80225

IN REPLY REFER TO:

July 16, 1997

U.S. Nuclear Regulatory Commission
ATTN: Mr. Alexander Adams, Jr
Non-Power Reactors and Decommissioning Directorate
Office of Nuclear Reactor Regulation
Washington DC 20555-0001

SUBJECT: ADDITIONAL INFORMATION (TAC M87035)

Dear Mr. Adams:

Attached is additional information that we believe will address your request dated April 22, 1997. This information has been reviewed by the facility's safety committee (Reactor Operations Committee) and has been found to form a complete and acceptable response to your request. This response is being executed in accordance with 10 CFR 50.30(b) as a signed original under oath or affirmation.

Further clarification or additional information may be received by contacting Mr. Tim DeBey at (303) 236-4726.

Sincerely,

Thomas D Fouch

Dr. Thomas Fouch
Reactor Administrator

The foregoing signature of Dr. Thomas Fouch only
was acknowledged before me this 16 day of
July, 1997.
My Commission expires 5/15/99

Notary Public

A001 1/1

## 1. EVALUATION OF FAILURE OF A 12 WT% TRIGA FUEL ELEMENT IN AIR, IN THE USGS FACILITY REACTOR BAY.

a. Resultant dose to a member of the public, at the fence of the Denver Federal Center, from a 12 wt% fuel failure in air:

The Denver Federal Center (DFC) is a 690 acre U.S. federal office complex that is located approximately 3 miles west of the Denver, CO city limits. The building that houses the reactor facility is in the northeastern quadrant of the Federal Center. The nearest DFC fence is approximately 1000 feet (305 meters) east of the TRIGA reactor facility, near Gate 2. Access to the Federal Center is controlled by security personnel at the entrance gates; however, Gate 2 is only manned and opened for several hours daily during normal employee commute periods.

Table 1 below lists the isotopes and calculated release activities for the worst case failure of a 12 wt% fuel element in air, in the reactor bay. These data are derived from analysis results submitted to your office in previous documents.

TABLE 1. RADIOISOTOPE RELEASE DATA FOR 12 wt% FUEL FAILURE

| Isotope | Release (Ci) | Isotope | Release (Ci) |
|---|---|---|---|
| Kr-83M | 3.15 X 10-2 | Kr-85M | 5.85 X 10-2 |
| Kr-85 | 3.15 X 10-3 | Kr-87 | 1.60 X 10-1 |
| Kr-88 | 2.54 X 10-1 | Kr-89 | 3.18 X 10-1 |
| Xe-131M | 1.73 X 10-3 | Xe-133M | 9.12 X 10-3 |
| Xe-133 | 3.84 X 10-1 | Xe-135M | 1.06 X 10-1 |
| Xe-135 | 3.65 X 10-1 | Xe-137 | 3.59 X 10-1 |
| Xe-138 | 3.18 X 10-1 | Br-82 | 7.24 X 10-3 |
| Br-83 | 2.96 X 10-2 | Br-84 | 5.22 X 10-2 |
| Br-85 | 6.39 X 10-2 | I-129 | 3.49 X 10-2 |
| I-130 | 2.96 X 10-2 | I-131 | 1.80 X 10-1 |
| I-132 | 2.54 X 10-1 | I-133 | 4.00 X 10-1 |
| I-134 | 4.53 X 10-1 | I-135 | 3.52 X 10-1 |

The release data above were input to the CAP88-PC computer program to calculate resultant doses at 305 meters. CAP88-PC is an EPA-developed code that uses a modified Gaussian plume model to estimate the dispersion of radionuclides simultaneously released from up to six sources. Dose and risk assessments can be performed on circular grids up to 50 miles from the release point. The program computes radionuclide concentrations in air, rates of deposition on ground surfaces, concentrations in food, and intake rates to people from ingestion of food produced in the assessment area. Estimates of radionuclide concentrations in food consumed are made by coupling the transport models with the NRC Reg. Guide 1.109 food chain models. The calculations performed herein conservatively assumed that no precipitation existed to remove airborne contamination and the wind was blowing eastward, directly toward the nearest fenceline. Wind data show that Denver's prevailing wind is from the south, with eastward winds occurring less than 5% of the time. Annual mean wind speed in Denver is 8.6 mph.

Since a residence does not exist at the fenceline, the calculations do not include any food pathways. The resultant effective dose calculations for the maximally exposed individual are given in Table 2 below. Results are shown for six Pasquill stability classes and for the five average wind speeds that are selectable in the CAP88PC code.

Conclusion: In general, the doses are the highest for stable winds at low speed, with a maximum of 27.1 mrem. This is well below the 10CFR20 limit of 100 mrem/yr for the general public from routine licensed operations.

TABLE 2. DOSE AT NEAREST DFC FENCE AFTER 12 wt% FUEL FAILURE

| Effective Dose (mrem) at 305m | Average Wind Speed (mph) | | | | |
|---|---|---|---|---|---|
| | 1.73 | 5.75 | 9.78 | 15.54 | 21.86 |
| Pasquill class A | | | 1.57 | | |
| B | | | 2.53 | | |
| C | 14.0 | 5.96 | 3.77 | 2.47 | 1.79 |
| D | 20.7 | 9.19 | 5.87 | 3.87 | 2.82 |
| E | 27.1 | 11.7 | 7.49 | 4.94 | 3.59 |
| F | 16.7 | 8.92 | 5.82 | 3.88 | 2.83 |

b. <u>Resultant dose to a member of the public at the nearest residence to the reactor</u>:

The nearest residence dose was calculated using CAP88PC with similar assumptions to those used in part a. The nearest residence is located north of the reactor facility at an approximate distance of 640 m. The only difference in the calculation assumptions was that the resident grew 10% of his vegetables at the residence, received an additional 40% of his vegetables from the affected area, and the remaining 50% from unaffected areas. Since the nearest dairy farm is about 15 miles away and the nearest beef cattle farm is over 4 miles away, all meat and milk consumption was still assumed to be uncontaminated. The radioisotope release data used were those in Table 1. The results of the fenceline analyses are given in Table 3 below.

Conclusion: Again, the highest dose result comes from a condition of low wind speed and high wind stability. The maximum calculated dose was 19.2 mrem, well below the 10CFR20 limit of 100 mrem/yr for the general public. Approximately half of this dose results from ingestion of contaminated vegetables.

TABLE 3. DOSE AT NEAREST RESIDENCE AFTER 12 wt% FUEL FAILURE

| Effective Dose (mrem) at 860m | Average Wind Speed (mph) 1.73 | 5.75 | 9.78 | 15.54 | 21.86 |
|---|---|---|---|---|---|
| Pasquill class A | | | 0.76 | | |
| B | | | 1.22 | | |
| C | 5.37 | 2.87 | 1.89 | 1.26 | 0.93 |
| D | 7.78 | 4.89 | 3.35 | 2.29 | 1.70 |
| E | 10.6 | 6.62 | 4.58 | 3.15 | 2.34 |
| F | 19.2 | 10.4 | 7.09 | 4.84 | 3.59 |

## 2. EVALUATION OF FAILURE OF AN 8.5 WT% TRIGA FUEL ELEMENT IN AIR, IN THE USGS FACILITY REACTOR BAY.

General Atomics data for 8.5 wt% fuel indicates a maximum radial power peaking factor of 1.45 and a maximum axial power peaking factor of 1.75. Radial peaking describes the change in power production from element-to-element, while axial peaking describes the power variation within the vertical fuel section of the element. At the licensed maximum power of 1000 kW in a nominal 100 element core, the result is a maximum power density of 14.5 kW in the hottest element. If more than 100 elements were in the core, the maximum power density would be less. The 100 element core is used for this analysis because it was the standard core used for the original hazards summary report. The 14.5 kW peak element power for the 8.5 wt% fuel is 65.9% of the 22 kW peak element power for the 12 wt% fuel. The fission rate and fission product inventory will change accordingly.

Table 4 gives the list of the gaseous fission product release that would occur in the event of a catastrophic rupture of an 8.5 wt% element that was operated for an infinite time at 14.5 kW. The reactor room airborne activity concentrations (in uCi/ml) were calculated using a fuel fission product release fraction of $3.146 \times 10^{-4}$, a reactor room volume of $3.48 \times 10^{8}$ cc and assuming complete mixing with no dilution from the ventilation system. Resulting air concentrations conservatively represent the highest peak levels possible in the reactor room.

TABLE 4. RADIOISOTOPE RELEASE DATA FOR 8.5 wt% FUEL FAILURE

| Isotope | Release (Ci) | Isotope | Release (Ci) |
|---|---|---|---|
| Kr-83M | 2.08 X 10-2 | Kr-85M | 3.87 X 10-2 |
| Kr-85 | 2.11 X 10-3 | Kr-87 | 1.05 X 10-1 |
| Kr-88 | 1.67 X 10-1 | Kr-89 | 2.09 X 10-1 |
| Xe-131M | 1.13 X 10-3 | Xe-133M | 5.98 X 10-3 |
| Xe-133 | 2.53 X 10-1 | Xe-135M | 6.98 X 10-2 |
| Xe-135 | 2.41 X 10-1 | Xe-137 | 1.36 X 10-1 |
| Xe-138 | 2.10 X 10-1 | Br-82 | 4.72 X 10-3 |
| Br-83 | 1.95 X 10-2 | Br-84 | 3.43 X 10-2 |
| Br-85 | 4.22 X 10-2 | I-129 | 2.30 X 10-2 |
| I-130 | 1.95 X 10-2 | I-131 | 1.19 X 10-1 |
| I-132 | 1.67 X 10-1 | I-133 | 2.64 X 10-1 |
| I-134 | 2.98 X 10-1 | I-135 | 2.33 X 10-1 |

At one hour after the fuel rupture, most of the 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. The krypton and xenon isotopes result in only submersion exposures. Data from Reg. Guide 1.109 are used only to supply data not in 10 CFR 20. The isotopes for which RG 1.109 data were used are Kr-89, Xe-137 and Br-85. Dose conversions from the 10 CFR 20 data (DAC and ALI) were performed using the following:

1 DAC-hr = 2.5 mRem, and 2000 DAC-hr = 1 ALI.
1 ALI = CEDE of 5 Rems or 50 Rems to critical organ/tissue.
Table 2, Col. 1 air concentrations give 50 mRem in 8760 hrs.

Table 5 on the next page lists the personnel exposures that result from a catastrophic failure of the postulated 8.5 wt% fuel element in air. This table provides data only for personnel who are on the Denver Federal Center, in close proximity to the reactor facility. Exposures from 10 CFR 20 data were calculated in DAC-hrs (for external exposure) and ALI's (for internal exposure) by continuous integration of the exposure rate, using a reactor room ventilation decay constant of 0.022 per minute and isotopic decay constant based on the respective half lives. Calculations from Reg. Guide 1.109 data used Table B-1 or E-7 and the average concentration over the time period stated in Table 5.

Reactor room submersion doses from krypton and xenon isotopes were adjusted for the room finite dimensions. A hemisphere of 550 cm radius was used to simulate the room. The equation for evaluating the dose reduction factor due to finite dimensions is $(1-e^{-ur})^{-1}$. The air density use (5000 ft. altitude) was 0.001116. The results are given in Table 6.

TABLE 5. PERSONNEL DOSES FROM 8.5 wt% FUEL CLAD FAILURE IN AIR

| Isotope | Occupational doses-mrem -stay time in reactor bay | | | | Non-occupational doses-mrem -stay time outside building | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 min | 5 min | 1 hr | 6 hr | 1 min | 5 min | 1 hr | 6 hr |
| Kr-83m | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kr-85m | <1 | 1 | 7 | 9 | 0 | 0 | <1 | <1 |
| Kr-85 | 0 | 0 | <1 | <1 | 0 | 0 | 0 | 0 |
| Kr-87 | 3 | 12 | 69 | 81 | <1 | <1 | <1 | 1 |
| Kr-88 | 10 | 47 | 304 | 384 | <1 | <1 | 1 | 1 |
| Kr-89 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Xe-131m | 0 | 0 | <1 | <1 | 0 | 0 | 0 | 0 |
| Xe-133m | <1 | <1 | <1 | <1 | 0 | 0 | 0 | 0 |
| Xe-133 | <1 | 1 | 10 | 14 | 0 | <1 | <1 | <1 |
| Xe-135m | 1 | 4 | 13 | 14 | 0 | <1 | <1 | <1 |
| Xe-135 | 3 | 13 | 89 | 118 | <1 | <1 | 1 | <1 |
| Xe-137 | <1 | <1 | 1 | 1 | <1 | <1 | [illegible] | <1 |
| Xe-138 | 6 | 26 | 87 | 88 | <1 | <1 | [illegible] | <1 |
| Br-82 | <1 | 2 | 11 | 16 | 0 | 0 | <1 | <1 |
| Br-83 | <1 | 1 | 3 | 3 | 0 | 0 | <1 | <1 |
| Br-84 | <1 | 1 | 5 | 5 | 0 | <1 | <1 | <1 |
| Br-85 | <1 | <1 | <1 | <1 | 0 | 0 | 0 | 0 |
| I-129 | 218 | 1040 | 7319 | 9983 | 1 | 7 | 52 | 71 |
| -thyroid | 7243 | 34645 | 243949 | 332755 | 51 | 255 | 1730 | 2360 |
| I-130 | 3 | 13 | 92 | 122 | 0 | <1 | <1 | 1 |
| -thyroid | 79 | 378 | 2610 | 3487 | 1 | 3 | 18 | 25 |
| I-131 | 169 | 811 | 5701 | 7764 | 1 | 6 | 40 | 55 |
| -thyroid | 6789 | 32427 | 228045 | 310432 | 48 | 230 | 1614 | 2201 |
| I-132 | 5 | 22 | 143 | 178 | <1 | <1 | 1 | 1 |
| -thyroid | 60 | 281 | 1786 | 2221 | <1 | 2 | 13 | 16 |
| I-133 | 80 | 381 | 2650 | 3572 | <1 | 3 | 20 | 25 |
| -thyroid | 2393 | 11402 | 79750 | 107432 | 17 | 81 | 564 | 758 |
| I-134 | 2 | 8 | 45 | 51 | <1 | <1 | <1 | 1 |
| -thyroid | - | - | - | - | - | - | - | - |
| I-135 | 16 | 78 | 527 | 692 | <1 | <1 | 4 | 75 |
| -thyroid | 326 | 1555 | 10545 | 13841 | 3 | 11 | 75 | 98 |

The exposures in Table 5 were then totalled over all isotopes to give the sums for both occupational workers and non-occupational workers in the immediate vicinity of the reactor. These sums are provided in Table 7. The conditions required to achieve the doses listed in Table 7 are: (1) maximum power peaking in a 8.5 wt% element to achieve 14.5 kW per element, (2) reactor operated continuously at full power for at least 40 days, 24 hours a day, (3) the 8.5 wt% element removed from the reactor tank instantly after shutdown and (5) a large cladding failure occurs in the element immediately after being removed from the water.

TABLE 6. DOSE REDUCTION FACTORS FOR FINITE ROOM DIMENSIONS

| Energy (MeV) | Dose reduction factor |
|---|---|
| 0.01 | 1.0 |
| 0.05 | 8.3 |
| 0.1 | 11.9 |
| 0.2 | 15.7 |
| 0.4 | 17.6 |
| 0.6 | 20.7 |
| 0.8 | 23.6 |
| 1.0 | 26.1 |
| 2.0 | 37.1 |

TABLE 7. TOTAL DOSES RECEIVED BY PERSONS IN IMMEDIATE VICINITY

| FISSION PRODUCT RELEASE EXPOSURE DATA | | | | | |
|---|---|---|---|---|---|
| | Occupational dose (mrem) | | | | |
| | 1 minute stay | 5 minute stay | 1 hour stay | 6 hour stay | Annual CFR Limit |
| TEDE | 514 | 2462 | 17074 | 23095 | 5000 |
| thyroid | 16889 | 80720 | 566686 | 770168 | 50000 |
| | Maximum non-occupational dose (mrem) | | | | |
| | 1 minute stay | 5 minute stay | 1 hour stay | 6 hour stay | Annual CFR Limit |
| TEDE | 6 | 20 | 123 | 234 | 100 |
| thyroid | 121 | 573 | 4014 | 5458 | ~3000 |

Experience at the GSTR from many high radiation alarm evacuation tests shows that the reactor facility would be evacuated within one minute and the building would be evacuated within 5 minutes. Facility security personnel would arrive within 5 minutes to evacuate as much of the surrounding area as is necessary. Under these conditions, the 10 CFR limits for occupational and non-occupational workers on the Denver Federal Center would not be exceeded. The simultaneous occurrence of the postulated 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 8.5 wt% TRIGA fuel can be operated safely in both steady state and pulsing reactors. 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.

a. <u>Resultant dose to a member of the public, at the fence of the Denver Federal Center, from an 8.5 wt% fuel failure in air</u>:

Evaluation of distant doses that would be received from the 8.5 wt% fuel failure in air were performed in the same manner as for the 12 wt% fuel in section 1.a. Table 4 data were input to the CAP88PC code to calculate resulting doses at the nearest DFC fence (305 meters from the reactor). These doses are given in Table 8 below.

This analysis does not include any food pathways since a residence does not exist at the DFC fenceline. The resultant effective dose calculations are for the maximally exposed individual, with results shown for six Pasquill stability classes and for the five average wind speeds that are selectable in the CAP88PC code.

TABLE 8. DOSE AT NEAREST DFC FENCE AFTER 8.5 wt% FUEL FAILURE

| Effective Dose (mrem) at 305m | Average Wind Speed (mph) 1.73 | 5.75 | 9.78 | 15.54 | 21.86 |
|---|---|---|---|---|---|
| Pasquill class A | | | 1.04 | | |
| B | | | 1.67 | | |
| C | 9.23 | 3.93 | 2.49 | 1.63 | 1.18 |
| D | 13.6 | 6.06 | 3.87 | 2.55 | 1.86 |
| E | 17.9 | 7.71 | 4.94 | 3.26 | 2.37 |
| F | 11.0 | 5.88 | 3.84 | 2.56 | 1.87 |

Conclusion: In general, the doses are the highest for stable winds at low speed, with a maximum of 17.9 mrem. This is well below the 10CFR20 limit of 100 mrem/yr for the general public from routine operations.

b. <u>Resultant dose to a member of the public, at the nearest residence to the reactor, from an 8.5 wt% fuel failure in air:</u>

Evaluation of the nearest residential doses that would be received after an 8.5 wt% fuel failure in air were performed in the same manner as for the 12 wt% fuel in section 1.b. Table 4 data were input to the CAP88PC code to calculate resulting doses at the nearest residence (860 meters from the reactor). These doses are given in Table 9 below.

For the nearest residence calculation, it was assumed that the resident grew 10% of his vegetables at the residence, received an additional 40% of his vegetables from the affected area, and the remaining 50% from unaffected areas. Since the nearest dairy farm is about 15 miles away and the nearest beef cattle farm is over 4 miles away, all meat and milk consumption was still assumed to be uncontaminated.

Conclusion: Again, the highest dose result comes from a condition of low wind speed and high wind stability. The maximum calculated dose was 12.7 mrem, well below the 10CFR20 limit of 100 mrem/yr for the general public from routine operations. About half of the nearest resident's dose results from ingestion of contaminated vegetables, mainly due to the iodine isotopes.

TABLE 9. DOSE AT NEAREST RESIDENCE AFTER 8.5 wt% FUEL FAILURE

| Effective Dose (mrem) at 860m | Average Wind Speed (mph) 1.73 | 5.75 | 9.78 | 15.54 | 21.86 |
|---|---|---|---|---|---|
| Pasquill class A | | | 0.50 | | |
| B | | | 0.80 | | |
| C | 3.54 | 1.89 | 1.25 | 0.83 | 0.61 |
| D | 5.13 | 3.22 | 2.21 | 1.51 | 1.12 |
| E | 6.99 | 4.36 | 3.02 | 2.08 | 1.54 |
| F | 12.7 | 6.86 | 4.67 | 3.19 | 2.37 |

## 3. DISCUSSION OF DIFFERENCES IN DOSES BETWEEN THE FAILURE IN AIR OF 8.5 WT% AND 12 WT% TRIGA FUEL ELEMENTS.

The primary difference in the consequences between failure of 8.5 wt% and 12 wt% fuel elements is due to the difference in fission product inventory. This difference is directly related to the power density, or fission density of the elements. The proposed amendment would restrict the 12 wt% power density to 22 kW/element, while the calculated maximum for the 8.5 wt% fuel currently in use is 14.5 kW/element. The use of 12 wt% fuel therefore gives an increase of 51.7% in the fission product inventory of the maximum power element in the reactor core.

Doses to the public, both at the nearest DFC fence and at the nearest residence are well below 100 mrem TEDE for the failure of either 8.5 wt% or 12 wt% fuel elements. At the nearest fence, the calculated maximum TEDE is 17.9 mrem for an 8.5 wt% element and 27.1 mrem for a 12 wt% element. At the nearest residence, the calculated maximum TEDE is 12.7 mrem for an 8.5 wt% element and 19.2 mrem for a 12 wt% element.

Although the use of 12 wt% fuel elements in the USGS reactor will increase the potential consequences of a fuel failure in air, the increases are of minor significance. The maximally exposed member of the public could receive an additional 9.2 mrem at the nearest DFC fence or an additional 6.5 mrem at the nearest residence. These increases are a small fraction of normal background radiation exposure and are well within the NRC allowed radiation doses to members of the public from licensed operations.