DOW

The Dow Chemical Company
Midland, Michigan 48667

Mr. Geoffrey Wertz
Research and Test Reactors Licensing Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Subject: Dow Chemical Company- Response to the Request for Additional Information for the renewed license of the TRIGA research reactor. License No. R-108; Docket No. 50-264

Enclosed the response to the request for additional information questions 26, 52, 54-57. Should you have any questions or need additional information, please contact the undersigned at 989-638-6932.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on May. 27, 2011

Melinda Krahenbuhl, Ph.D.
Director
Dow TRIGA Research Reactor

Subscribed and sworn to before me this 27th day of May, 2011

Kimberly Hartman
Notary Public
Gladwin County, Michigan
My Commission Expires:
12/15/2016

KIMBERLY ANN HARTMAN
NOTARY PUBLIC - STATE OF MICHIGAN
COUNTY OF GLADWIN
My Commission Expires December 15, 2016
Acting in the County of Gladwin

cc: Wayde Konze, R&D Director - Analytical Sciences

A020

DTRR response to questions 26, and 52, and 54- 57
May 2011

26. NUREG–1537, Part 1, Section 5.6, “Nitrogen-16 [N^{16}] Control Systems” requests the applicant to provide a description of the nitrogen control system employed and how personnel exposure to N^{16} is consistent with the facility's as low as reasonably achievable (ALARA) Program. DTRR SAR, Section E.6, does not provide a description of the system or information for estimating the dose.

DTRR response:

Personnel dosimetry records show that radiation exposure has historically been very low at this facility. The reactor room is typically unoccupied during reactor operation. This practice will not be altered and is consistent with the as low as reasonably achievable. At 250 kW, the dose rate at the top of the pool is 30 mrem/hr. With the cooling system in operation the transport time increases due to the interruption of the vertical convective column. Dose rate measured at the top of the pool is reduced to 5 mrem/hr.

52. NUREG–1537, Part 1, Section 13.1.1, “Maximum Hypothetical Accident” requests the applicant to provide a maximum hypothetical accident (MHA) and demonstrate that it bounds all potential credible accidents at the facility. The MHA for TRIGA reactors is typically the failure of one fuel element in the air with the release of gaseous fission products. DTRR SAR M.1.3, analyzes a fuel failure in the pool, but it does not meet the expectation of being a bounding accident analysis. Please provide an analysis of the MHA for the DTRR that bounds all other accident analysis. Please include all assumptions, sequence of events and the potential radiological consequences.

DTRR response

The rupture of a fuel element would result in the release of fission products. Fuel elements are rarely, if ever, removed from the pool water, but, in order to bound the consequence analysis, it is assumed that the damaged fuel element is outside the reactor pool at the time of the accident. This type of event has been analysis by F. C. Foushee and R. H. Peters, “Summary of TRIGA Fuel Fission Product Release Experiments”, Gulf Energy and Environmental Systems report A-10801, 1971. Similar conclusions are reported by S. C. Hawley and R. L. Kathren, “Credible Accident Analyses for TRIGA and TRIGA-fueled Reactors”, NUREG/CR-2387, PNL-4028 (1982). Assuming that the reactor has been operated at 1 MW with zero decay time the fission product inventory predicted by RSAC for a single element is presented in Tables 1 and 2. The use of the Dow TRIGA research reactor over the past 40 years indicates that the reactor has not been continuously operated for a sufficient period of time to achieve saturation of the fission product inventory and is not likely to be so operated, therefore the inventory is conservatively estimated and the doses estimated are for emergency planning only.

The fraction of gaseous fission products that will be released during a failure of a TRIGA reactor fuel element at a temperature of less than 350° C is 1.5×10^{-5} (Foushee and Peters, 1971; Stahl, 1982). The volume of the reactor room is about 130 cubic meters, with a turnover rate of about 50 cubic meters per minute. However, no credit was taken in the consequence calculations for reductions in air concentrations due to the ventilation of the room. The effective dose equivalent for worker exposure was calculated assuming perfect mixing the room and instantaneous release to the reactor room.

Restricted area

The effective dose equivalent to an individual in the restricted area enveloped in the radioactive cloud of released halogens and noble gases was calculated as the sum of the inhalation dose of the halogens and the submersion dose of the noble gases. Dose conversion factors for inhalation were taken from 10 CFR 20, Appendix B, column 2 for the calculation of effective dose equivalent to the whole body and for the dose calculations to the thyroid for the iodine compounds. For the thyroid dose from the bromine compounds and the submersion dose, dose conversion factors from FGR No. 11 (Environmental Protection Agency, 1988) were used. Dose rates from inhalation and submersion doses in the reactor room are calculated to be 0.43 mrem /hour. The committed dose equivalent to the thyroid is calculated as 7.2 mrem/hour. Calculations of the dose rate by isotope are summarized in Tables 1 and 2.

Unrestricted area

Doses to unrestricted areas are calculated using a normal ventilation rate for the reactor room of 50 m^3/min. Using the Pasquill categories' and a Gaussian approach to dispersion, the maximum concentration of fission products to a member of the public is at the fenceline, 23 m from the reactor building. The short range is due to the low height of the ventilation exit, 2.73 meters (8 ft) above the building. The wind is assumed to be blowing in the direction of the fence at the time of the accident, and conservative atmospheric stability conditions are conservatively assumed. The total effective dose equivalent at the unrestricted location is 0.11 mrem/hour and the committed dose equivalent to the thyroid at this location is 3.72 mrem/hr. Calculations of the dose rate by isotope for offsite exposures are summarized in Tables 3 and 4.

<u>References</u>

F.C. Foushee and R. H. Peters, Summary of TRIGA Fuel Fission Product Release Experiments, Vol. 11, General Atomic Company Report Gulf EES-A108011; and S. Langer and N. L. Baldwin, Fission Product Release Experiments on Uranium-Zirconium Hydride Fuels, Vol. I, General Atomic Company Report Gulf GA-A10781 (1971).

D. Stahol. Fuels for Research and Test Reactors, Status Review: July 1982. Argonne National Laboratory report ANL-83-5 (1982).

Table 1. Dose Inside the Reactor Room from Halogens from Fuel Element Rupture Accident Scenario

Halogens	Activity (Ci)	Concentration in Reactor Room (Ci/m^3)	Inhalation Dose Conversion Factor (Sv/Bq)	Dose Contribution (rem/hr)
Br-83	[redacted]	[redacted]	2.41E-11	7.51E-08
Br-84	[redacted]	[redacted]	2.61E-11	1.51E-07
Br-84M	[redacted]	[redacted]	2.61E-11	2.87E-09
Br-85	[redacted]	[redacted]	2.61E-11	1.90E-08
Br-87	[redacted]	[redacted]	2.61E-11	3.32E-08
I-129	[redacted]	[redacted]	4.69E-08	8.34E-12
I-130	[redacted]	[redacted]	7.14E-10	3.84E-09
I-131	[redacted]	[redacted]	8.89E-09	1.49E-04
I-132	[redacted]	[redacted]	1.03E-10	2.58E-06
I-133	[redacted]	[redacted]	1.58E-09	5.71E-05
I-134	[redacted]	[redacted]	3.55E-11	1.57E-06
I-135	[redacted]	[redacted]	3.32E-10	1.21E-05
Total Halogens	[redacted]			**2.23E-04**

Table 2. Dose Inside the Reactor Room from Noble Gases from Fuel Element Rupture Accident Scenario

Noble Gases	Activity (Ci)	Concentration in Reactor Room (Ci/m3)	Submersion Dose Conversion Factor (Sv/Bq)	Dose Contribution (rem/hr)
Kr-83M	[redacted]	[redacted]	2.98E-11	3.09E-07
Kr-85	[redacted]	[redacted]	4.70E-13	1.54E-10
Kr-85M	[redacted]	[redacted]	2.98E-11	7.32E-07
Kr-87	[redacted]	[redacted]	1.42E-10	6.97E-06
Kr-88	[redacted]	[redacted]	3.60E-10	2.51E-05
Kr-89	[redacted]	[redacted]	3.60E-10	3.23E-05
Kr-90	[redacted]	[redacted]	3.60E-10	3.18E-05
Kr-91	[redacted]	[redacted]	3.60E-10	2.38E-05
Xe-131M	[redacted]	[redacted]	1.48E-12	8.97E-10
Xe-133M	[redacted]	[redacted]	5.38E-12	1.89E-08
Xe-133	[redacted]	[redacted]	6.07E-12	7.33E-07
Xe-135M	[redacted]	[redacted]	7.53E-11	1.73E-06
Xe-135	[redacted]	[redacted]	4.68E-11	5.99E-06
Xe-137	[redacted]	[redacted]	1.92E-10	2.28E-05
Xe-138	[redacted]	[redacted]	1.92E-10	2.31E-05
Xe-139	[redacted]	[redacted]	1.92E-10	1.89E-05
Xe-140	[redacted]	[redacted]	1.92E-10	1.34E-05
Total Noble Gases:	[redacted]			**2.08E-04**

Table 3. Downwind Dose from Halogens from Fuel Element Rupture Accident Scenario

Halogens	Release Rate (Ci/sec)	Inh DCF (Sv/Bq)	Downwind Concentration (Ci/m^3)	Dose Rate (rem/hr)
Br-83	[redacted]	2.41E-11	[redacted]	1.99E-08
Br-84	[redacted]	2.61E-11	[redacted]	4.01E-08
Br-84M	[redacted]	2.61E-11	[redacted]	7.63E-10
Br-85	[redacted]	2.61E-11	[redacted]	5.04E-09
Br-87	[redacted]	2.61E-11	[redacted]	7.63E-09
I-129	[redacted]	4.69E-08	[redacted]	2.21E-12
I-130	[redacted]	7.14E-10	[redacted]	1.02E-09
I-131	[redacted]	8.89E-09	[redacted]	3.95E-05
I-132	[redacted]	1.03E-10	[redacted]	6.83E-07
I-133	[redacted]	1.58E-09	[redacted]	1.52E-05
I-134	[redacted]	3.55E-11	[redacted]	4.16E-07
I-135	[redacted]	3.32E-10	[redacted]	3.22E-06
Total:				**5.91E-05**

Table 4. Downwind Dose from Noble Gases from Fuel Element Rupture Accident Scenario

Noble Gases	Release Rate (Ci/sec)	Submersion Dose Conversion Factor (Sv/Bq)	Downwind Concentration (Ci/m^3)	Dose Rate (rem/hr)
Kr-83M	[redacted]	2.98E-11	[redacted]	8.20E-08
Kr-85	[redacted]	4.70E-13	[redacted]	4.08E-11
Kr-85M	[redacted]	2.98E-11	[redacted]	1.94E-07
Kr-87	[redacted]	1.42E-10	[redacted]	1.85E-06
Kr-88	[redacted]	3.60E-10	[redacted]	6.65E-06
Kr-89	[redacted]	3.60E-10	[redacted]	8.21E-06
Kr-90	[redacted]	3.60E-10	[redacted]	6.58E-06
Kr-91	[redacted]	3.60E-10	[redacted]	2.51E-06
Xe-131M	[redacted]	1.48E-12	[redacted]	2.38E-10
Xe-133M	[redacted]	5.38E-12	[redacted]	5.03E-09
Xe-133	[redacted]	6.07E-12	[redacted]	1.95E-07
Xe-135M	[redacted]	7.53E-11	[redacted]	4.60E-07
Xe-135	[redacted]	4.68E-11	[redacted]	1.59E-06
Xe-137	[redacted]	1.92E-10	[redacted]	5.84E-06
Xe-138	[redacted]	1.92E-10	[redacted]	6.13E-06
Xe-139	[redacted]	1.92E-10	[redacted]	4.07E-06
Xe-140	[redacted]	1.92E-10	[redacted]	2.02E-06
Totals:				**4.64E-5**

The accident will be terminated by the Facility director once the releasable gaseous fission products have been released and cleared from the reactor room, area radiation monitors return to normal levels, and the fuel rod has been recovered and stored in a secure location (core or storage rack). The Facility Director with advice from the First Responders including the Radiation Safety officer terminates the accident. The event will be transitioned in to clean-up based on dose rate.

54. NUREG–1537, Part 1, Section 13.1.5, "Mishandling or Malfunction of Fuel" requests the applicant to provide analyses regarding the mishandling or malfunction of fuel. DTRR SAR, Section M.1.3, provides an analysis that assumes that a damaged fuel element is submerged in the reactor pool at the time of the event and only halogens and noble gases are released. The DTRR SAR does not discuss how the accident terminates and does not provide exposures to the staff or the public. Please provide additional information regarding this analysis indicating how the accident terminates and the dose consequences of this accident analysis.

DTRR response:

The rupture of a fuel element would result in the release of fission products into the water. Fuel elements are rarely, if ever, removed from the pool water, so it is assumed that the damaged fuel element is submerged in the reactor pool at the time of the accidents, and only halogens and noble gases may be released to the atmosphere. This type of event has been analysis by F. C. Foushee and R. H. Peters, "Summary of TRIGA Fuel Fission Product Release Experiments", Gulf Energy and Environmental Systems report A-10801, 1971. Similar conclusions are reported by S. C. Hawley and R. L. Kathren, "Credible Accident Analyses for TRIGA and TRIGA-fueled Reactors", NUREG/CR-2387, PNL-4028 (1982)

The dose consequences for this accident are bounded by the MHA discussed in question 52. The accident will be terminated by the Facility director once the releasable gaseous fission products have been released and cleared from the reactor room, area radiation monitors return to normal levels, and the fuel rod has been recovered and stored in a secure location (core or storage rack). The Facility Director with advice from the First Responders including the Radiation Safety officer terminates the accident. The event will be transitioned into clean-up based on dose rate.

55. NUREG–1537, Part 1, Section 13.1.3, "Loss of Coolant" requests the applicant to provide analysis that assures that doses to the public that could result from a loss of coolant accident do not exceed 10 CFR Part 20 limits. DTRR SAR, Section M.1.1, Table 7 presents exposures resulting from a loss of coolant accident. There is no statement regarding occupational or public dose limits and whether they are met. Please explain this accident analysis in further detail and in terms of meeting the regulatory limits.

DTRR response:

The water level in the surrounding area is above the core height and therefore tank breach will not result in a total loss of coolant. However, the analysis was completed for an uncovered core after an extended period of operation at 300 kW. The results are in the following table.

Time after complete loss of coolant	Direct radiation – 18 ft directly above core (R/hr)	Indirect Radiation shield top edge of the tank (R/hr)
10 seconds	3000	0.78
1 day	360	0.090
1 week	130	0.042
1 month	35	0.012

These calculations show that in the event of a loss-of-cooling accident, an individual who does not stand directly over the core could work for several days at the top of the reactor pool one day after shutdown without exceeding the annual dose limit of 5 rem. This allows for adequate time to make repairs to the system or install alternate shielding allowing the repairs to be completed.

The direct radiation from the unshielded core would be highly collimated by the pool structure and therefore would not normally give rise to a public hazard.

56. NUREG–1537, Part 1, Section 13.1.9, "Mishandling or Malfunction of Equipment" requests the applicant to provide analysis regarding equipment mishandling or malfunction. DTRR SAR, Section M.1.7, describes an accident that involves dropping a lead transfer cask in the pool but does not discuss the accident results and dose consequences. Please provide information pertaining to the results and consequences of the accident scenario with the dropped lead cask.

DTRR response:

Dropping of a lead cask in to the pool may result in damage to the rods drives, control rods and fuel cladding, and rotary specimen rack dependent on orientation of lead cask. The DTRR does not own a transfer cask, nor is the DTRR equipped with a crane or hoist. However, if rod drive mechanisms are damaged, the reactor is shut down, specifically without the drives the control rods remain inserted in core. If the lead cask lands on the core, the support structure would be damaged resulting in a non critical core configuration. The reactor is effectively shut down. If the lead cask damages the fuel cladding. Several elements could be damaged. The resulting dose consequences could be conservatively estimated by multiplication of the dose consequences of the MHA. From the response to RAI 52, the failure of 1 fuel element would result in dose rates of 0.43 mrem/hr in the reactor room, so all the failure of all eighty fuel elements would result in dose rates of 34 mrem/hr.

57. NUREG–1537, Part 1, Section 13.1.6, "Experiment Malfunction" requests the applicant to provide analysis of an experiment malfunction event. DTRR SAR, Section M.1.4, does not include analysis of an experiment failure with release of radioactivity. Please provide an analysis and consequences of an experiment malfunction for the experiment with the highest potential release of radioactivity.

DTRR response:

All experiments are reviewed before insertion and all experiments are separated from the fuel cladding by at least on barrier such as the pneumatic transfer and irradiation tube, and central thimble. All experiments that could damage components of the reactor are required by technical specification to be double encapsulated. Samples are typically under 8 grams, with a majority of the samples irradiated consisting of carbon, hydrogen and oxygen (plastic and organics). Calculations of dose to workers and members of the public were performed for the complete release of an I-131 experiment, because I-131 has the most limiting inhalation dose conversion factor of the iodine isotopes of interest. Consequence calculations performed were identical to the calculations performed for the fuel failure release described in the response to RAI 52, above. The dose consequences of the release of 10 microCi of I-131 is 3.0 mrem/hr total effective dose equivalent for workers in the room, and 100 mrem/hr committed effective dose equivalent to the thyroid. Members of the public could be exposed to dose rates of no more than 0.013 mrem/hr total effective dose equivalent and 0.44 mrem/hr committed effective dose equivalent to the thyroid. A summary of the consequence calculations is available in Table 5 and 6, below.

Table 5. Iodine Experiment Accident Scenario Consequences

Isotope	**Activity (Ci)**	**Concentration in Reactor Room (Ci/m3)**	**Inhalation Dose Conversion Factor (Sv/Bq)**	**Dose Rate (rem/hr)**
I-131	0.00001	7.69e-08	8.89e-09	3.04e-03

Table 6. Downwind Dose from I-131 from Iodine Experiment Failure Accident Scenario

Isotope	**Release Rate (Ci/sec)**	**Inh DCF (Sv/Bq)**	**Downwind Concentration (Ci/m3)**	**Dose Rate (rem/hr)**
I-131	6.41E-08	8.89e-09	3.40E-10	1.34E-05