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Document Control Desk
US Nuclear Regulatory Commission
Washington, DC 20555

Dear Sirs:

Three Mile Island Nuclear Station, Unit 2 (TMI-2)
Operating License No. DPR-73
Docket No. 50-320
Criticality Safety Evaluation for Coagulants

Attached for your review and approval is the criticality safety evaluation for the use of the coagulants previously addressed in GPU Nuclear letters 4410-86-L-0213 dated December 15, 1986, and 4410-86-L-0216 dated December 31, 1986. These submittals evaluated the introduction of coagulant into the reactor coolant system (RCS) and the defueling canisters and showed that the presence of the coagulant in either the RCS or the defueling canisters would not adversely impact criticality safety. For the Defueling Water Cleanup System (DWCS) filter canister, however, the assurance of canister subcriticality was further ensured by the presence of borated water in and surrounding the canisters while being stored at TMI-2.

The attached evaluation addresses criticality safety in the RCS and the defueling canisters with no credit taken for borated water in the case of the defueling canisters. This evaluation shows that the presence of any amount of coagulant in the canisters (regardless of canister type) or the RCS does not alter previous canister criticality evaluations. Therefore, the canisters containing coagulant can be dewatered and shipped safely via the NuPac 125-B shipping casks without compromising subcriticality.

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Per the requirements of 10 CFR 170, an application fee of $150.00 is enclosed.

Sincerely,

F. R. Standerfer
Director, TMI-2

FRS/RDW/eml

Attachment

Enclosed: GPU Nuclear Corp. Check No. 002474

cc: Regional Administrator - Region 1, Dr. T. E. Murley
Director - TMI-2 Cleanup Project Directorate, Dr. W. D. Travers

Criticality Safety Evaluation of Coagulant and Body Feed Materials

1.0 Purpose and Scope

The purpose of this evaluation is to assess the criticality safety issues associated with the proposed use of two coagulants and a body feed material at TMI-2. The scope of the evaluation is limited to the criticality safety aspects of using these materials in the TMI-2 reactor coolant system (RCS) and defueling canisters. The RCS will be treated with small amounts of coagulant and body feed to improve the performance of the defueling water cleanup system filter canisters. The precautions and controls to be implemented as part of the design and operation of systems which will inject the coagulant and body feed material are discusssed in Reference 1.

2.0 Criticality Prevention

Criticality safety of the TMI-2 RCS and defueling canisters is maintained by use of soluble boron (4350 ppm) and solid boron carbide, respectively. Use of coagulants and body feed material in the RCS or canisters must not compromise the function or significantly increase the burden of these mechanisms for ensuring criticality safety. Hence, the following sections will evaluate the physics of the criticality safety issue. The coagulant materials to be evaluated will be referenced as vendor products 1182 and 1192. The body feed material to be used is diatomaceous earth (d.e.). The chemical formula for each of the materials is given below:

vendor product 1192	$(C_8H_{16}NCl)_n$
vendor product 1182	$(C_5H_7N_6)_n$
diatomaceous earth	SiO_2 (primarily)

2.1 Reactor Coolant System Criticality

Criticality safety in the reactor coolant system is maintained by the presence of water borated to a concentration of at least 4350 ppm. This boron concentration has been demonstrated (Ref. 2) to be adequate for maintaining the entire TMI-2 fuel inventory subcritical under bounding assumptions. These bounding assumptions include optimum fuel moderation conditions and worst credible fuel configuration. As stated in References 1 and 3, coagulants 1182 and 1192 and diatomaceous earth have been tested to determine their effect on soluble boron in the reactor coolant. These tests have verified that the addition of the noted chemicals to the RCS will not cause precipitation of boron.

As stated earlier, the concentrations of coagulant injected into the RCS will be small. To enter the reactor vessel, the material must first pass through the defueling water cleanup system (DWCS) filters. The accumulation of a non-borated mass of insoluble coagulant in the RCS, which might coagulate and cause boron displacement, is not credible. Since the coagulant material will not form a non-borated mass, the boron sampling requirements presently instituted for the RCS will provide adequate warning if the boron concentration decreases below the administrative limit of 4950 ppm. Additionally, it would take in excess of 5 tons of coagulant material dissolved in the reactor vessel water to pose a criticality concern. Thus, given that the boron concentration of the RCS will be maintained above the administrative limit, the addition of these materials will not be a criticality safety concern.

2.2 Defueling Canister Criticality

Criticality safety of the defueling canisters is assured by using fixed boron carbide material inside each canister. The coagulant and body feed materials will collect primarily in the filter canisters; however, the following technical assessment is independent of the canister type (i.e., fuel, knockout, or filter). As with the RCS, the poison requirements for the defueling canisters were determined using bounding analytical assumptions. One of the key assumptions was the existence of optimum moderation conditions for the fuel. The moderator was assumed to be unborated water. The acceptability of the coagulant and body feed material will be demonstrated by assessing the impact on neutron multiplication of the canisters with and without the added materials.

2.2.1 Evaluation of 1192

Vendor coalesce 1192 is a cationic coagulant. The coagulant to be used is only 20 w/o of the polymer $C_8H_{16}NCl$ and 80 w/o unborated water. When the polymer is added to water the chemical reaction causes the chlorine to disassociate from the molecule leaving a cation to coalesce suspended solids. The evaluation will quantify the net effect of the increased moderation caused by the additional hydrogen and the increased neutron absorption due primarily to the nitrogen. The monomeric molecular weight (amu) of 1192 with the chlorine is 161.7 and 126.3 without it. Given the polymer is 20 w/o of the solution and the density of the solution (1.03 gm/cm^3), the polymer density was found to be 1.18 gm/cm^3. Additionally, it is assumed that the specific gravity of the polymer does not change with the loss of the chlorine atom.

Using the above information, the number densities of the molecule and component atoms of the dry material were determined based on a molecular weight of 161.7 amu for the molecule. Using data from Reference 4, the macroscopic absorption cross section of 1192 was determined to be 0.03 cm^{-1} while that of unborated water is

0.02 cm^{-1}, resulting in an excess amount of absorption. Using a macroscopic cross section of boron in water per ppm of 4.27E-05 cm^{-1}, the excess absorption was correlated with an equivalent boron concentration of 225 ppm. The change in neutron multiplication, k_∞, resulting from the additional equivalent boron was obtained using data from Reference 5. Using this data, k_∞ was found to drop 0.044Δk, for a boron concentration change from zero to 225 ppm.

The next step in assessing 1192 was to examine the increase to k_∞ due to the increased moderation. This is accomplished by using the "four factor formula" from nuclear reactor theory (Reference 6). Using the values calculated for the four parameters, the increase in k_∞ due to the 1192 polymer was found to be 0.007.

The net effect on the infinite neutron multiplication, k_∞ caused by the presence of the 1192 polymer is estimated to be:

$$\Delta k = 0.007 - 0.044 = -0.037$$

If the assessment provided above for 1192 is repeated using a molecular weight of 126.3 amu to obtain the elemental number densities, the negative effect on k_∞ is estimated to be:

$$\Delta k = 0.029 - 0.087 = -0.058$$

In both of the above cases, the thermal neutron absorption by chlorine is conservatively excluded from the evaluation.

Although the evaluation is made by determining the net change to k_∞ the conclusions reached apply to finite canister geometries, i.e., k_{eff}.

Thus, the addition of the coagulant and body feed materials will not have an adverse effect on criticality safety of the defueling canisters.

2.2.2 Evaluation of 1182

The hydrogen number density for 1182 was determined using the monomeric molecular weight (amu) of 151.2 and a polymer density of 1.52 gm/cm^3. The range of bulk densities for 1182 (melamine formaldehyde) was given in Reference 7 as 1.47 - 1.52 gm/cm^3. Using this data, the number of hydrogen atoms per unit volume was more than 30% less than that of unborated water. Additionally, using thermal cross sections for hydrogen and nitrogen of 0.332 and 1.9 barns respectively, the neutron absorption for 1182 per hydrogen atom is a factor of 5.9 larger than that for water. Hence, vendor product 1182 is both a poorer moderator and a stronger neutron absorber than unborated water. Thus if 1182 were to replace water in defueling canisters containing fuel, a significant reduction in neutron multiplication would result.

2.2.3 Evaluation of Diatomaceous Earth

Diatomaceous earth will be used as the body feed material for the filter canisters. The material consists primarily of silicon dioxide, SiO_2. The neutron moderation and absorption ability of the material is essentially zero, thus the material will not have an adverse effect on criticality safety.

3.0 Summary

The use of coagulants 1192 and 1182 and diatomaceous earth in the reactor coolant system and defueling canisters has been evaluated and found to have no adverse effects on criticality safety. The canister evaluation applies to all canister types and takes no credit for the soluble poison that will reside in the canisters while stored at TMI-2. Thus the conclusion that there is no adverse effects on canister neutron multiplication also applies to canister shipment offsite.

4.0 References

1. Safety Evaluation Report for the Addition of Coagulants to the Reactor Coolant System, GPU Nuclear letter from F. R. Standerfer to W. D. Travers, # 4410-86-L-0213, dated December 15, 1986

2. Criticality Report for the Reactor Coolant System, Rev. 0, 15737-2-N09-001, October 1984

3. Use of Coagulants, GPU Nuclear Letter from F. R. Standerfer to W. D. Travers, # 4410-86-L-0216, dated December 31, 1986

4. Neutron Cross Section Vol. II, BNL-325, Third Edition January 1976

5. The Effect of Boron and Gadolinium Concentrations on Calculated Neutron Multiplication Factor of $U(3)O_2$ Fuel Pins in Optimum Geometries, ORNL/CSD/TM-218, J. T. Thomas

6. Nuclear Reactor Analysis, by J. J. Duderstadt and L. J. Hamilton, John Wiley & Sons, Inc., Copyright 1976, page 83

7. CRC Handbook of Chemistry and Physics