TMI-2 DEFUELING CANISTER
REACTIVITY CALCULATIONS

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ABSTRACT

Detailed Monte Carlo reactivity calculations have been carried out for each of the three types of TMI-2 defueling canisters. All design criteria have been satisfied with due consideration to credible accident contingencies and with adherence to conservative modeling procedures.

INTRODUCTION

The design criteria for the TMI-2 defueling canisters include reactivity restrictions that assure an adequate subcriticality margin for credible contingencies of loading, transport, or storage. This paper describes the calculations performed to assure compliance with these criteria during the evolution of the canister concepts and for the verification of the final designs.

Throughout the course of this work the calculational models employed have been tailored to provide a large margin of conservatism in addition to that inherent in the design criteria. In addition, the computed results have been biased in a conservative sense to allow for calculational uncertainties. As a result of these procedures the final canister designs assure continued criticality safety of the core material during the planned transfer and storage operations at the TMI-2 site.

CANISTER TYPES

The defueling canisters are of three types with different internal geometrical configurations and functional requirements as follows:

(1) primary fuel canisters designed to accommodate large chunks of coherent fuel debris, and large structural parts of fuel assemblies.

(2) flow-thru screening canisters or, "knockout" canisters, designed to accept fragments up to about whole fuel pellet size and to retain fragments larger than 180 microns,

(3) flow-thru filter canisters designed to retain particles larger than 0.5 microns.

The general configurations of the three canister types are shown in Fig. 1. In the reference designs the different canister types have the same overall dimensions, 355.6 mm OD x 3810 mm length, and utilize 6.35 mm wall thickness SS pipe as the outer shell. In the primary fuel canisters the fuel is confined to a central compartment of square cross section formed by a Boral™/stainless steel shroud and LICON™ concrete is used as a filler in the outer lobe segments. In both the knockout and filter canisters the fuel region extends to the outer shell.

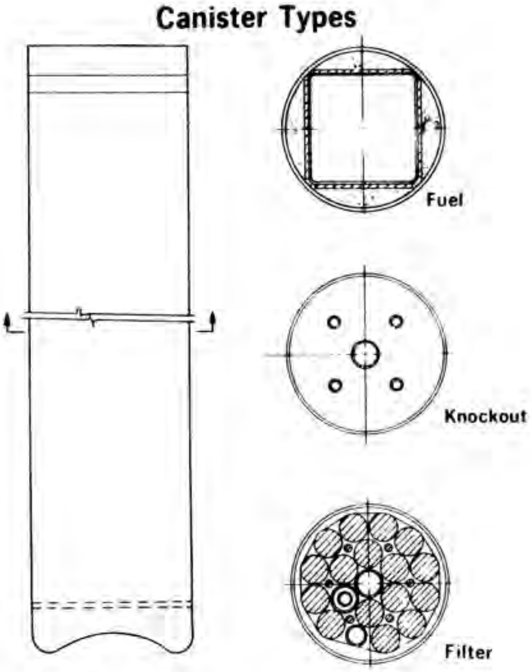

Fig. 1. Canister Configurations

The Boral shroud constitutes the fixed poison assembly in the fuel canister. The minimum surface density of boron-10 in the Boral plates is 0.040 gm/cm^2. For the knockout and filter canisters the fixed poison consists of B_4C vibrapacked to a minimum density of about 1.45 gm/cm^3 in stainless steel tubes. In the knockout canister there is a 50.80 mm ID axial poison tube and 4 satelite tubes of 20.57 mm ID. The filter canister has a single 50.80 mm ID axial poison tube.

REACTIVITY CRITERION

The reactivity criterion applied in establishing the poison requirements is that k-effective shall not exceed 0.95 for any canister or array of canisters in any physically achievable configuration during defueling, canister transfer, or canister storage. The 0.95 limit is applied after allowance has been made for all known uncertainties in the calculated k-effective.

COMPUTER CODES AND CROSS SECTIONS

The primary code used in the calculations is the Monte Carlo criticality code KENO4.[1] Parametric optimization calculations were carried out with the NULIF[2] code for the fuel region, and weighted fuel region cross sections were calculated with NITAWL[3] and XSDRNPM[4]. A 123-group cross section representation was used in all transport calculations. The basic cross section set used in these analyses was the 123-group XSDRN[5] neutron set generated from ENDF/B-II data. This cross section set was used because it, in conjunction with KENO4, has been extensively benchmarked against critical experiments at B&W. This provides a basis for evaluation of calculational versus measurement uncertainties associated with the KENO4 calculations. The basic cross section set was processed by NITAWL to generate a working library set with the U-238 cross sections Doppler broadened and self-shielded. The fuel cell cross sections were then weighted by the XSDRNPM program to incorporate pin cell spatial effects into the homogenized fuel cross sections used in KENO4.

SCOPE OF THE CALCULATIONS

The reactivity calculations fall into the following categories:

- fuel optimization
- evaluation of preliminary designs
- detailed design verification
- normal transfer and storage cases
- hypothetical accident cases

The basic fuel optimization was done with NULIF cell calculations with variation of fuel lump size and volume fraction in pure water. Further optimization studies considered temperature variations, caked fuel particles, water holes, and reflector effects in neutron transport calculations with XSDRNPM and KENO4.

Various geometric configurations were evaluated with approximate modeling in the KENO4 standard geometry during the preliminary design phase, but the final design verification was done in relatively fine detail with the KENO4 "generalized" geometry representation. The interaction of the loaded fuel canisters with the various transfer devices and building walls and passages as well as storage rack configurations was evaluated in explicit KENO4 calculations. Many special cases were also studied. These included hypothetical accident cases of dropped canisters lying on top of the storage rack or standing alongside the rack, displaced canister poison material, low density moderator effects, extreme temperature variations, fused fuel lumps, etc.

MODELING CONSERVATISM

The key assumptions employed in the calculational models for this study were the following:

- unburned fuel all of the highest U-235 enrichment including manufacturing tolerances, even though only 1/3 of core was of this enrichment
- optimal fuel lump size, shape, and fuel/H_2O ratio
- no soluble boron or core control component poisons
- no cladding or core structural material
- isothermal conditions at 10°C
- infinite array of canisters on square pitch of 457.2 mm
- no storage rack structural material
- bounding damaged canister configurations

From the conservatism of these assumptions, a significant extra margin of safety in the canister designs can be inferred. However, no credit is taken for this in the comparison of the calculated results with the k-effective design criteria.

RESULTS AND CONCLUSIONS

The key results of these calculations are summarized in TABLE I. An allowance of 2.0% Δk in the single canister cases and 2.3% Δk in the array cases has been made for possible bias in the KENO4 representation. This was determined from a wide range of benchmark comparisons.[6,7] An additional 2σ statistical uncertainty (typically in the neighborhood of 1%) has also been included in accordance with standard safety procedures. These results satisfy the k-effective upper limit criterion by substantial margins in all cases and provide assurance that the planned TMI-2 defueling and storage operations can proceed safely.

TABLE I

Results of 3-D KENO4 Criticality Calculations

Description	Maximum k-effective
Filter Canister	
Single, Standard Configuration	0.804
18" Array, Standard Configuration	0.834
Single, Accident Configuration	0.892
Fuel Canisters	
Single, Standard or Accident Configuration	0.857
18" Array, Standard Configuration	0.877
Knockout Canister	
Single, Standard Configuration	0.873
18" Array, Standard Configuration	0.911
Single, Accident Configuration	0.887

REFERENCES

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