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September 22, 1987

US Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Dear Sirs:

Three Mile Island Nuclear Station, Unit 2 (TMI-2)
Operating License No. DPR-73
Docket No. 50-320
Defueling Canister Technical Evaluation Report, Revision 4

Attached for your review and approval is Revision 4 to the Technical Evaluation Report (TER) for the TMI-2 Defueling Canisters. This revision modifies Section 3.1, "Canister Structural Evaluation," to reflect that a fuel canister can withstand a single load drop of 602 lbs. (dropped in air) or 850 lbs (dropped in water) vice the current limitation of 350 lbs. and 550 lbs., respectively. The revision is based on the dynamic load drop test described in Reference 14. For multi-occurrences, the present maximum load drop restriction remains valid.

It is noteworthy that the supporting analysis for the proposed revision is based on permitting some permanent deformation of the lower support plate and the support plate/shell weld. However, based on the attached analysis, this deformation would not impair the functioning of the recombiner packets in the canister lower head. Conversely, the ability to dewater the canister could be affected if the drain tube/bulkhead weld is damaged as a result of a load drop. In such an event, the ability to dewater the affected canister would be evaluated on a case-by-case basis.

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This revision also incorporates the information submitted via GPU Nuclear letter 4410-87-L-0092 dated June 10, 1987, concerning an increase in the pore size of the filter bundle in some filter canisters.

For the purposes of this submittal, only the pages affected by this revision are attached.

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

Sincerely,

FRStanderfer

F. R. Standerfer
Director, TMI-2

FRS/RDW/eml

Attachment

Enclosed: GPU Nuclear Corp. Check No. 006984

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

GPU Nuclear

TER 3527-016 REV 4

ISSUE DATE September 1987

☐ ITS
☒ NSR
☐ NITS

DIVISION

TECHNICAL EVALUATION REPORT

FOR

Defueling Canisters

ORIGINATOR [signature] DATE 7/29/87 9/1/87
D.S. Williams per Telecon ... 9/21/87
TAB 9-1-87

COG ENG [signature] DATE 7-31-87 T. Van per Telecon ... 9/21/87

RTR [signature] 9/15/87 DATE 8/4/87
DJS per Telecon ... 9/21/87

COG ENG MGR. D.R. Buchanan per [initials] 9/1/87 DATE 8/10/87
Telecon DRB per Telecon ... 9/21/87

FORM 4000-ENG-7310.08-1 (5/84)

Rev.	SUMMARY OF CHANGE	Approval	Date
0	Issued for initial use.		3/85
1	Update to incorporate design change from vibrapacked B_4C powder to sintered B_4C pellets, discussion if maximum particle size expected in filter canister, increase in load limit on fuel canister lower support plate from 350 to 550 lbs., addition of k_{eff} criteria for plant accident condition (0.99), discussion of effects on criticality analyses caused by a) change to B_4C pellets, b) lower storage pool water temperature, and c) fuel particle size, addition of section regarding hydrogen controls within the canister.		9/85
2	Update to incorporate change to allow fuel particles greater than standard whole pellets size to introduced into knockout and fuel canisters. Specific reference to the Fines/Debris Vacuum System was also deleted from Section 2.3 to allow additional application of the knockout canister.		3/86
3	Update to incorporate use of "deep-bed" filters, coagulants and diatomaceous earth in DWCS, to correct statements regarding the exposed quantity of catalyst in dewatered canisters, to present canister pressure after 25% void volume dewatering, and to reflect the use of deep suction in the DWCS.		5/87
4	Update to Section 3.1 to reflect that a fuel canister can withstand a one-time load drop of 602 lbs. (in air) and 850 lbs. (in water). Additionally, this revision reflects an increase in the pore size of the filter bundle in some of the filter canisters per GPU Nuclear letter 4410-87-L-0092 dated June 10, 1987.		

2.4 Filter Canister

As part of either the DWCS or the Fines/Debris Vacuum System, the filter canisters are designed to remove small debris particles from the water. Externally, it is similar to the other canister types. The filter assembly bundle that fits inside the canister shell was designed to remove particulates down to 0.5 (nominal) microns. In an effort to reduce clogging, some filter canisters may be equipped with filter bundles using a filter media that is designed to remove particulates down to approximately 16 microns. The significant differences between these filter bundles and the 0.5 micron bundles are the larger size of the pore openings in the filter media, and the 16 micron filter bundle can be back-flushed. The 16 micron filter bundles may be flushed at 20 psid (for 10 cycles) and 25 psid (for one cycle). Flow into and out of the filter canister is through 2 1/2" cam and groove quick disconnect fittings (Figure 2.4-1).

The internal filter assembly bundle consists of a circular cluster of 17 filter elements, a drain line and a neutron absorber assembly (Figure 2.4-2). The influent enters the upper plenum region, flows down past the support plate, through the filter media and down the filter element drain tube to the lower sump. The flow is from outside to inside with the particulate remaining around the outer perimeter of the filter elements. The filtered water exits the canister via the drain line.

A filter element consists of 11 modules. Each module consists of pleated filter media forming an annulus around a central, perforated drain tube (Figure 2.4-3). Fabricated from a porous stainless steel material, the media is pre-coated with a sintered metal powder to control pore size. Bands are placed around the outer perimeter of the pleated filter media to restrict the unfolding of the pleats.

The filter assembly bundle is held in place by an upper support plate and lower header. The lower header is welded to the outer shell of the canister to provide a boundary between the primary and secondary side of the filter system. The upper header is equipped with a series of openings to allow for the passage of the influent into the filter section of the canister and to protect the filter media from direct impingement of particles carried in the influent flow. Six tie rods position the upper plate axially relative to the lower support plate.

The filter canister has a central neutron absorber rod that is comprised of an outer strong back tube surrounding a 2.125" O.D. tube filled with sintered B_4C pellets.

The filter canisters are not expected to contain significant quantities of fuel particles larger than 850 microns. The filter canisters are used with the DWCS and the defueling vacuum system. The DWCS is used to process both spent fuel pool/fuel transfer canal water and reactor coolant system (RCS) water. In the RCS, the DWCS suction is located in the upper region of the reactor vessel, where large fuel debris (i.e., >850u) would not be expected to be suspended in solution. The DWCS has been modified to allow suction from the Reactor Vessel annulus at approximately the 296' elevation. At this lower elevation, it is possible that larger than 850 micron size particles may be introduced into the filter canisters. However, a screen has been placed in the inlet pipe to the filter canister to prevent these larger particles from entering the filter canisters. The spent fuel pool/fuel transfer canal is not expected to contain significant quantities of fuel particles larger than 850 microns. Consequently, the DWCS filter canisters are not expected to contain significant quantities of fuel particles larger than 850 microns.

When the filter canisters are used in conjunction with the defueling vacuum system, they are located downstream of the knockout canisters. Proof of principle testing (Reference 11) has shown that for the planned vacuum system flowrates, minimal quantities, if any, of 850 micron or larger sized particles would be carried out of the knockout canister. Additionally, the discharge of the knockout canisters are equipped with a 841 micron screen to prevent larger fuel particles from exiting the knockout canister. Thus the vacuum system filter canisters are not expected to contain significant quantities of fuel particles larger than 850 microns.

3.0 TECHNICAL EVALUATION

This section summarizes the safety issues which were evaluated during the design of the canisters. These issues deal with the expected performance of the canisters during normal operations and various design basis events. Safety issues which were evaluated include structural forces on a canister as a result of a drop accident, criticality issues associated with both single canisters and canisters in the storage racks and the canister/storage rack interface, including any constraints on the storage rack design.

3.1 Canister Structural Evaluation

3.1.1 Canister Structural Evaluation During Normal Operations

A structural evaluation has been performed (Reference 1) which addresses both the loads imposed on the canister during normal operations (loading and handling) as well as postulated drops. Additional testing was performed on 16 micron filter modules to demonstrate that these filter modules have greater load carrying capabilities than the original 0.5 micron filter modules (Reference 15).

A combination of analytical methods and component testing is used to verify the adequacy of the design. Acceptance criteria for normal operation is based on the ASME Pressure Vessel Code, Section VIII, Part UW (lethal).

Normal operation of the canister imposes very small loads on the canister internals. The largest load on the internals is the combined weight of the debris and internals. The configuration of the canisters is such that only the lower plate assembly that supports both the debris and internals experiences any significant loads. Results of the stress analysis shows a large margin of safety for the lower plate assembly and its weld to the outer shell for all canister types. The canister shell is subject to ASME Code, Section VIII standards. Verification of the canister shell structural design to the ASME requirements has been performed (Reference 1). The canisters are designed for a combined (canister, debris, and water) static weight of 3500 pounds.

During normal handling operations (lifting), the static plus dynamic loading considered in the design of the handling features of the canister is 1.15 times the static lifted weight. Results from the structural evaluation show an acceptable margin of safety considering the stress design factors specified in NUREG-0612 and ANSI N14.6.

Normal loading of the fuel canister presents two cases for evaluation. First is the capability of the lower support plate to absorb the impact of debris accidentally dropped into the canister. Results of the dynamic impact evaluation show that the support plate can accommodate loads of up to 350 lbs (23% of a fuel assembly) dropped, in air, the full canister length without a failure of the lower plate to shell weld.

This weight limit increases to 550 lbs. (in air weight) if credit is taken for the drag forces of the water in the canister. Second is the verification that placement of debris within the canister will not rupture the shroud's inner wall. This would expose the Boral sheets to the RCS water which could cause corrosion of the boral. However, examination of the shrouds subjected to drop tests (reference 10) indicate that the inner wall is resistant to debris impacts and scrapes.

A dewatering system is used to remove water from all canisters prior to shipment. During this procedure, a pressure differential is developed across the debris screen, lower support plate and drain tube. The maximum pressure differential allowed, via a safety relief valve in the dewatering system, across canister internal components during dewatering is 55 psi. The canister internals are designed for a maximum differential pressure of 150 psi although filter media differential pressure is limited by design to 60 psid. Hence, an adequate margin of safety exists for the dewatering process.

The canisters are capable of withstanding enveloping accidents. Vertical drops of 6'-1 1/2" in air followed by 19'-6" in water, or 11'-7" in air are considered along with a combination of vertical and horizontal drops. These drops were analyzed to bound a drop in any orientation. For these cases, the structural integrity of the poison components must be maintained and the canister must remain subcritical. Deformation of the canister is acceptable. Although not expected based on the B&W drop test results, leakage of core material from the canister, up to its full contents, is allowed provided that the contents left in the canisters remain subcritical. An equivalent drop in air was calculated for the worst case and this equivalent air drop was used as the basis for the structural analysis. Structural analysis methods were used to determine the extent of the deformation of the shell and canister internals. Impact velocities were calculated for the specified canister drops. Based on these velocities, strain energy methods were used to compute the impact loads associated with the various postulated drops. Vector combinations of the horizontal and vertical components were used to determine the effect of a drop at any orientation.

In the vertical drop cases (reference 10), the same deformation will occur regardless of the canister type, since it is shell dependent. Test results from the actual canister drops have verified that for the bottom impact, all deformation occurs below the lower support plate in the lower head region. An upper bound shell deformation was computed using the ANSYS (Reference 5) computer code and the results are presented in Figure 3.1-1 along with the actual test results.

To determine the consequences of a vertical and horizontal drop on the filter and knockout canisters, their internals were analyzed with finite element methods using the ANSYS computer program. This analysis incorporated the actual non-linear properties of the material. Geometric constraints imposed by the shell were accounted for by limiting the displacement of the supports.

In the filter canister, criticality control is provided by the central B_4C poison rod coupled with the mass of steel in the filter element drain tubes and tie rods. Using the end caps of the filter modules as deflection limiters, the entire tube array deflection is limited to 1.6" under postulated accidents. This analysis is conservative because it does not take into account the 5 circumferential bands around the array or the viscosity of the filter cake bed, both of which would tend to maintain the standard spacing. Using the maximum calculated deformed geometry (before the array bounced back closer to its original position), the criticality criterion given in section 3.2 was met. The above analysis was performed considering the original 0.5 micron filter media design. Based on the results of the testing performed in Reference 15 which showed that the filter modules equipped with the larger pore opening filter media had a greater load carrying capability, it is concluded that the deflections discussed above are bounding when applied to canisters using filter modules with larger pore opening filter media.

In the knockout canister, criticality control is provided by the central B_4C poison rod coupled with four absorber rods. Results from the structural analysis show that the poison rods remain essentially elastic during all postulated accidents and the maximum instantaneous displacements are less than 0.75 inch. The minor modifications made to some of the knockout canisters to convert them to "deep-bed" filters (Section 2.3) are within the bounds of the values used in the analysis and testing of the knockout canisters. Thus, the "deep bed" filters are expected to exhibit similar structural behavior as the knockout canisters during a drop accident. As in the case of the filter canister, the resultant deformed geometry successfully met the criticality criterion given in section 3.2.

The fuel canisters, with their square-within-a circle geometry, exhibit different drop behavior than the other canisters. For both the vertical and side drops, the fuel canister internals will not experience significant deformations other than the shell deformations discussed above. Lightweight concrete filling the void between the square inner shroud and the circular outer shell provides continuous lateral support to both the outer shell and the shroud. This results in a distributed loading function for horizontal drops resulting in no calculated deformation to the shroud shape. Testing has demonstrated that the lower support plate remains in place for design drops while supporting a mass equal to the shroud, payload and the concrete. The lack of significant deformation after a drop (reference 10) makes the criticality analysis for the standard design applicable to the drop cases as well.

3.1.2 Fuel Canister Structural Evaluation For A One-Time Maximum Allowable Load Drop

A dynamic load drop test has been performed (Reference 14) which addresses a maximum load drop into a fuel canister as a one-time event.

Based on the drop test, the maximum weight that can be permitted to be dropped from the top of the fuel canisters, in air, into a fuel canister is 602 lbs. as a one-time event. For loads dropped from the top of the fuel canister through water starting at zero velocity, the allowable one-time value is 850 lbs. (measured in air). For multi-occurrences, the allowable drop weight is limited to 550 lbs. (dropped in water as measured in air).

The analysis in Reference 14 is based on permitting some permanent deformation of the lower support plate and the support plate/shell weld but not enough to cause damage to the recombiner packets in the lower head. Canister shell stresses remain in the elastic range. The ability to dewater the canister could be affected in the event that the drain tube/bulkhead weld is damaged as a result of a load drop. In such a case, the ability to dewater the canister would be evaluated on a case-by-case basis.

3.2 Canister Criticality Evaluation

Criticality calculations were performed to ensure that individual canisters as well as an array of canisters will remain below the established k_{eff} criterion under normal and faulted conditions. The criticality safety criterion established is that no single canister or array of canisters shall have a k_{eff} greater than 0.95 during normal handling and storage at the TMI-2 site. For plant accidents (e.g., drained spent fuel pool), the criticality safety criterion established is a $k_{eff} \leq 0.99$. These criteria are satisfied for all canister configurations.

The "deep bed" filters do not alter the placement of the poison rods in the knockout canisters and the d.e. and/or sand added to these canisters has less moderating ability than water; thus, the criticality evaluations performed for the knockout canisters would bound the "deep-bed" filters. In addition, the criticality evaluations performed on the knockout canisters following drop accidents would bound dropped "deep-bed" filters since the structural behavior of the "deep-bed" filters is similar to the knockout canisters.

Coagulants and d.e. used in DWCS to improve filter canister performance has been evaluated in Reference 12. This evaluation has shown that the addition of these materials in the canisters would not adversely impact the criticality evaluations presented herein. Additionally, the accumulation of coagulants and d.e. in the canisters would not adversely affect the conclusions presented in Attachment 2 regarding the subcriticality of the stored canisters in a postulated dry storage pool.

The computer codes used in this work were NULIF, NITAWL, XSDRNPM and KENOIV (References 6, 7, 8 and 9). The NULIF code was used primarily for fuel optimization studies in a 111 energy group representation. NITAWL and XSDRNPM were used for processing cross sections from the 123 group AMPX master cross section library. NITAWL provides the resonance treatment and formats the cross section for use by either XSDRNPM or KENOIV. In most cases, XSDRNPM cell weighted cross sections were used in the KENOIV calculations but for some comparative fuel optimization runs the NITAWL output library was used directly by KENOIV.

The calculational models assume the following conditions for the canister contents:

1. Batch 3 fresh fuel only
2. Enrichment: batch 3 average + 2σ (highest core enrichment)
3. No cladding or core structural material
4. No soluble poison or control material from the core
5. Optimally moderated, stacked, standard whole fuel pellets
6. Canister fuel regions are completely filled without weight restrictions
7. Uniform 50°F temperature
8. B-10 surface density was assumed to be 0.040 gm/cm^2 in the Boral used for the fuel canister. (Actual B-10 surface density will be 0.040 gm/cm^2 with a 95/95% confidence level in the testing to provide at least a 2σ margin.)
9. B_4C density used is the poison tubes for the filter and knockout canister was assumed to be 1.35 gm/cm^3 with the boron weight percent assumed to be 70%. (Actual B_4C density will be at least 1.38 gm/cm^3 with a boron weight percent meeting requirements for ASTM-C-750 Type 2 B_4C powder, minimum boron weight percent 73%.)

Optimization studies were performed to determine the value of these parameters. These optimization studies are presented in Reference 1 along with other parametric studies performed for special cases.

The KENO analysis employs a fuel model that bounds all debris loading configurations. Three basic configurations were analyzed for each canister: a single canister surrounded by water, an array of canisters in the storage pool and a disrupted canister model resulting from an enveloping drop. The standard canister configuration assumed that some minimum degree of damage could have occurred in the canisters during normal loading operations. All the canisters analyzed in an array were assumed to have this minimum damage. A 17.3" center-to-center spacing was analyzed for the array cases. The 17.3" center-to-center spacing accounts for all storage rack tolerances and is the minimum center-to-center spacing possible for any two canisters. The canisters are assumed to be loaded with debris consisting of whole fuel pellets enriched to 2.98 w/o, optimally moderated with 50°F unborated water. The analysis will provide conservative results and bound any actual configuration including draining of the canisters during the dewatering operation. For accident conditions, it is assumed that optimized fuel is present in both normal fuel locations and in all void regions internal to the canister. Filling all void regions with fuel has the effect of adding fuel to the canister after a drop.

The canister shell, including the lower head, is identical for all three canisters. The cylindrical shell is modeled using the maximum shell OD of 14.093" and the nominal 0.25" wall thickness. The model explicitly describes the concave inner surface but squares off the rounded corners. This increases the volume of the lower head.

All three canisters contain catalytic material for hydrogen recombination in both the lower and upper head. This material and its structural supports are not included in the models. The volume occupied by these materials is replaced with fuel. In addition, the protective skirt and nozzles on the upper canister head are not modeled.

The storage rack cases assume the canisters are stored in unborated water with a 17.3" minimum center-to-center spacing. Sensitivity studies were performed on the nominal 18" center to center spacing to determine the effect of a canister dropped outside of the rack. These analysis show that k_{eff} <0.95 for canisters dropped outside the rack as long as the side of the dropped canister does not come within 2" of the side of the nearest canister in the rack. This requirement is met by the storage rack design (Reference 2).

Three cases are examined for a dropped canister: a vertical drop, a horizontal drop and a combined vertical and horizontal drop. The shell deformation is essentially the same for all cases. For these drops, the cylindrical shell is assumed not to deform. Any deviation from the cylindrical shape would increase the surface to volume ratio and increase the neutron leakage from the system. In the lower head region of the shell, a tear drop shape expansion is assumed to occur. The bottom head is modeled as a flat plate with the internal components resting on it. To bound all drop cases, the canister was assumed to rotate during a drop and land on its head. A similar tear drop shape will result. Both of these cases were merged into a single model that assumes the tear drop deformation at both the top and bottom with the internals displaced to the flattened lower head surface. For the combined vertical-horizontal drop, the radial displacement of the internal components is combined with the double tear drop model. This drop model bounds any conceivable drop configuration by exceeding conservative stress estimates of deformation.

Results

The results of KENO, using basic three dimensional canister models are presented in Table 3-1. These results represent bounding values for any configuration of the canisters at TMI-2.

Basically, they show that for any configuration, the effective multiplication factor, with uncertainties included, will be less than 0.95. Due to the conservatism built into the models, the k_{eff} of any actual configuration will be less than these bounding values.

Four (4) assumptions used in the analyses reported in Table 3-1 have been reevaluated. The affected assumptions are:

1. type of poison used in the filter and knockout canisters,

2. storage pool water temperature,

3. fuel particle size, and

4. change in filter media.

The values reported in Table 3-1 for the filter and knockout canisters are based on the assumption that the poison tubes for the canisters are filled with vibrapacked B_4C powder. Actual fabricated filter and knockout canisters contain compressed sintered B_4C pellets. This change resulted in a small reduction to the diameter of the poison in the canisters which results in a small increase in the multiplication value (k_{eff}) of the two canister types. Based on analyses the increase in multiplication will not exceed 0.4% Δk.

The values reported in Table 3-1 assume a minimum temperature of 50°F for all canister types. For canisters stored in the spent fuel pool the temperature could be as low as 32°F. Explicit criticality array calculations were not performed at this lower temperature. Rather, an evaluation was performed to determine the maximum increase in multiplication due to cooling from 50°F to 32°F. The maximum change in multiplication was determined to be an increase of 0.1% Δk.

The results reported in Table 3-1 are also based on the assumption that no single fuel mass greater than a whole fuel pellet exists in the TMI-2 core. Examinations of the core have indicated that fuel melting may have occurred. To assess the impact of this possibility, an evaluation was performed to determine the k_∞ for the most reactive batch 3 fuel particle size. The k_∞ for the optimum size particle was only 0.07% Δk higher than the k_∞ for the standard whole pellet. The corresponding increase in k_{eff} would be approximately the same magnitude. Thus, there is no limit on the sizes of fuel particles that can be placed in the fuel and knockout canisters.

The results reported in Table 3-1 for the filter canisters are based on the original 0.5 micron filter media design. Some filter canisters may be equipped with a filter media that removes particulates only down to approximately 16 microns. Since the filter canisters using the new filter media are otherwise identical to the original filter canisters, this change in media will not significantly affect the canister neutron multiplications. Therefore, it is concluded that the normal configuration results for the filter canister, as reported in Table 3-1, are bounding for filter canisters equipped with modules using the new filter media.

To address the accident configuration for filter canisters using the new filter media, Reference 15 demonstrated that the new filter modules had greater load carrying capabilities than the original filter modules. Thus, the deflections of the canister internals determined for canisters with the original modules bound the deflections expected for canisters with the new modules. Therefore, the accident configuration filter canister results reported in Table 3-1 are bounding for canisters employing the new filter media.

In conclusion, the changes in k_{eff} resulting from the four (4) modified assumptions will not result in exceeding the k_{eff} criterion of 0.95 for the cases reported in Table 3-1.

3.3 Canister Hydrogen Control Evaluation

A generic feature of the canisters is the recombiner catalyst package incorporated into the upper and lower heads of all the canisters. The catalyst recombines the hydrogen and oxygen gases formed by radiolytic decomposition of the water trapped in the damp debris. This reduces the buildup of internal pressure in the canister and keeps the gases below the flammability limit. The redundant locations ensure that a sufficient quantity of catalyst is available for any canister orientation in which hydrogen might be generated (e.g., an accident which leaves a canister upside down). Test results (Reference 4) have shown that the catalyst will perform effectively when dripping wet, but not when submerged.

A single catalyst bed, which contains at least 100 grams of catalyst, is incorporated in the upper heads of the fuel canisters. Two catalyst beds, each containing at least 50 grams of catalyst, are incorporated in the upper heads of the filter and knockout canisters. Four catalyst beds, each containing at least 25 grams of catalyst, are installed in the lower heads of all the canisters. Thus, each canister contains at least 200 grams of catalyst. The catalyst beds were designed to meet the shape and volume requirements established from testing by RHO (Reference 4).

Canister dewatering in the FHB will ensure that a sufficient quantity of catalyst would be exposed (not submerged in water) in a dewatered canister in any orientation. This sufficient quantity of catalyst will be 50% more catalyst than required. The required quantity of catalyst is determined by catalyst testing that considers catalyst contaminations which may occur during canister fabrication and loading and chemical additions to improve DWCS filter performance and to control microbiological growth in the RCS. Reference 13 provides a detailed evaluation on canister dewatering criteria in order to expose a sufficient quantity of catalyst to achieve a minimum safety factor of 1.5.

The maximum predicted gas generation rate in a canister has been determined by two separate models; (1) the maximum theoretical gas generation rate and (2) the maximum realistic gas generation rate. The maximum theoretical gas generation rate was determined by Rockwell Hanford Operations (RHO) in their document RHO-WM-EV-7 (GEND-051) for purpose of developing the catalytic recombiner bed design. The maximum realistic gas generation rates were determined by GPU for purposes of predicting canister internal pressures during periods when the canisters are water solid.

Both models are based on the Turner paper, "Radiolytic Decomposition of Water in Water-Moderated Reactors Under Accident Conditions", referenced in the RHO report. The basic relationship is:

$H_2 = (W)(F)(G)(r)\ 8.4 \times 10^{-3}$ liters/hour

where:
F = fraction of β and γ energy absorbed in water
G = H_2 generation value in moles/100 eV
r = ratio of peak to average decay heat energy in the fuel debris
W = ionizing radiation per canister (watts)
8.4×10^{-3} = unit conversions (L ev/W.hr)

For the maximum theoretical generation, the above factors are maximized as follows:

- o W - the maximum quantity of fuel debris in any canister, not including residual water weight or weighing accuracy, is assumed. ($W = 54.2$)
- o F - The fraction of β and γ energy absorbed is conservatively high and large amounts of water are also assumed to be available for absorbtion which is in excess of what is possible in the canisters. ($F = 0.2$)
- o G - The hydrogen gas generation value is based on a) completely turbulent/boiling conditions when the radiolytic gases are instantly removed from the generation site and b) no build up of hydrogen overpressure which tends to retard radiolysis. ($G = 0.44$)
- o r - The ratio of peak-to-average decay heat energy in the fuel is based on the most active region of an undamaged core. This assumes the fuel is intact and not scattered to other regions. ($r = 1.9$)

For the maximum realistic generation of hydrogen and oxygen, the worst case realistic factors for the damaged TMI core are used as follows:

- o W - The maximum quantity of fuel debris expected in any canister is used which includes allowances for residual water and weighing accuracy. ($W = 50$)
- o F - The fraction of β and γ energy absorbed is based on the maximum amount of water possible in an actual canister. ($F = 0.07$)
- o G - The hydrogen gas generation value is based on the actual worst case core debris conditions expected in a canister which includes lower temperature, quiescent conditions. ($G = 0.12$)
- o r - The ratio of peak to average decay heat energy in the fuel debris is based on the worst case conditions in the damaged TMI core. ($r = 1.4$)

The resulting hydrogen/oxygen generation rates for the two models are:

	Max. Theoretical liter/hour	Max. Realistic liter/hour
H_2	7.6×10^{-2}	5.0×10^{-3}
O_2	3.8×10^{-2}	2.5×10^{-3}
Total	1.14×10^{-1}	7.5×10^{-3}

The generation of other gases was not considered. Since the amount of contaminants in the RCS is small, the generation of other gases from the radiolytic decomposition of these contaminants is not expected to be significant.

Using the maximum realistic gas generation rate of 0.0075 liters/hour and assuming no recombination or scavenging of oxygen, the 25 psig relief valve is estimated to first open in approximately 25 days for the worst case canister. Released gas will be vented through the pool water directly to the containment or fuel handling building and is such a small quantity that it will cause no combustion concerns in the atmosphere of these buildings.

To address the issue of canister pressurization resulting from failure of the 25 psig relief valve a second relief valve is installed on the canisters. This relief valve will ensure that canister pressure does not exceed the design limit of 150 psig. The additional relief valve will make the canister single failure proof with regards to pressurization. This second valve will also be installed in such a manner to eliminate common mode failure of the two pressure relief valves.

The recombiner catalyst is ineffective when it is under water. An evaluation has been performed to determine how long it takes an undewatered canister to reach 150 psig if the 25 psig relief valve fails closed. This time for the worst case canister is 139 days. A similar concern exists for the dewatered canister should a significant amount of oxygen scavenging occur and the 25 psig relief valve fails closed. Assuming no recombination, (i.e. complete oxygen scavenging) the canister will reach the design pressure in 2362 days for a fully loaded fuel canister with 25% void volume following dewatering.

If the relief valve should fail open while the canisters are being stored there is the possibility that fuel debris can be released into the pool water. If contaminants are released into the pool the defueling water cleanup system (DWCS) can be used as necessary to limit the contamination level of the water. Hence, a failed open relief valve does not pose a safety concern. Additionally, given that it is planned, although not required, to dewater the canisters shortly after they are loaded, pressurization of the canisters caused by hydrogen/oxygen generation will be minimal and the relief valve is not expected to open.

Although not considered a credible event, the consequences of a hydrogen ignition inside a canister has been evaluated. The maximum pressure that can be reached inside a canister under normal conditions, because of the 25 psig relief valve, is approximately 42 psia. This pressure includes the 25 psig set pressure and 5 feet of water submergence. Under the assumption that the recombiner catalyst does not function properly, a flammable mixture of hydrogen and oxygen can accumulate within a canister. If an ignition of this mixture is postulated, an overpressurization of the canister could occur. The ultimate stresses will be reached for various canister components at the estimated pressures:

- canister shell - 2160 psi
- fuel canister bolts - 2900 psi
- threaded connections - 2500 psi

Considering the large margin that exists between these pressures and the maximum, normal condition canister pressure (i.e., approximately a factor of 50), the overpressurization resulting from an ignition of hydrogen within the canister is not expected to affect the overall canister integrity.

TABLE 3-1

Results of 3D KENO Criticality Calculation

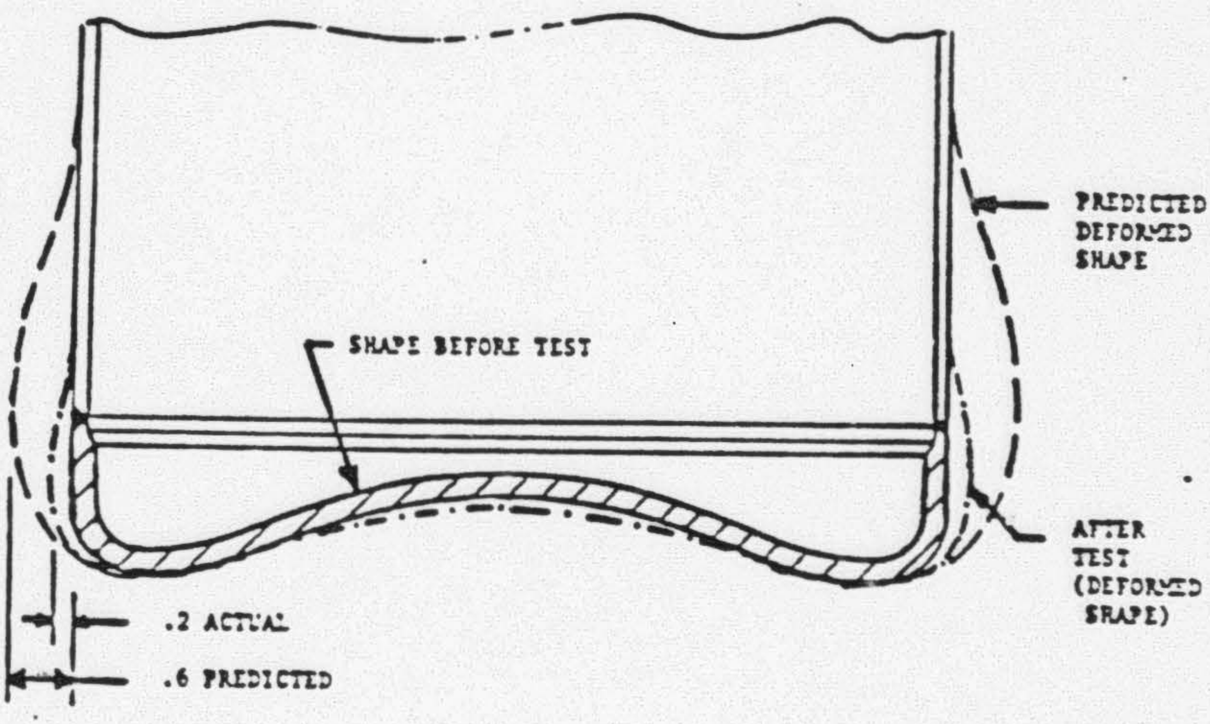
Description	$k_{eff}+2\sigma$	Histories	Maximum k_{eff}*
Filter Canister**			
Single, Ruptured Filters	0.795 ± 0.024	9331	0.839
17.3" Array, Ruptured Filters	0.823 ± 0.021	52374	0.867
Vertical Drop, Ruptured, without filter screens	0.798 ± 0.025	8127	0.843
Horizontal Drop, Ruptured, without screens	0.843 ± 0.010	15050	0.873
Combined Horizontal/Vertical Drop, Ruptured, without screens	0.851 ± 0.021	44849	0.892
Fuel Canister			
Single, Standard Configuration	0.825 ± 0.012	15050	0.857
17.3" Array, Standard Configuration	0.829 ± 0.025	6321	0.877
Knockout Canister**			
Single, Standard Configuration	0.835 ± 0.018	10535	0.873
17.3" Array, Standard Configuration	0.877 ± 0.015	11438	0.915
Vertical Drop, Single	0.843 ± 0.019	9933	0.882
Horizontal Drop, Single	0.853 ± 0.008	26488	0.881
Combined Horizontal/Vertical Drop, Single	0.851 ± 0.016	12943	0.887

*k_{eff} + 2σ + calculational bias (see Reference 1)

**results are based on vibrapacked B_4C powder in the poison tubes

FIGURE 3.1-1

SHELL DEFORMATIONS - VERTICAL DROP (ALL CANISTERS)



4.0 RADIOLOGICAL CONSIDERATIONS

The canisters are designed to be loaded with core debris from the TMI-2 RCS. These canisters do not contain internal shielding and must be shielded during all handling and storage operations.

The shielding requirements for the various canister operations (e.g. loading, handling, and storage) are discussed in reference 3.

Personnel exposure from the loaded canisters will be addressed in Reference 3 as part of the canister handling sequence.

5.0 10 CFR 50.59 EVALUATION

Changes, Tests and Experiments, 10 CFR 50, paragraph 50.59, permits the holder of an operating license to make changes to the facility or perform a test or experiment, provided the change, test or experiment is determined not to be an unreviewed safety question and does not involve a modification of the plant technical specifications. A proposed change involves an unreviewed safety question if:

a. The probability of occurrence or the consequences of an accident or malfunction of equipment important to safety previously evaluated in the safety analysis report may be increased; or

b. the possibility for an accident or malfunction of a different type than any evaluated previously in the safety analysis report may be created; or

c. the margin of safety, as defined in the basis for any technical specification, is reduced.

The defueling canisters replace the fuel cladding lost during the accident as the barrier for containing the fuel. As discussed in Section 1.1 of this TER, the purpose of this evaluation is to show that the canisters are designed to remain safe under normal operation and handling conditions as well as postulated drop accidents and storage. The scope of the evaluation relates only to design aspects and not in field canister use which is addressed in the Safety Evaluation Report for Defueling of the TMI-2 Reactor Vessel (Reference 3). On this basis the scope of this 10 CFR 50.59 Evaluation is limited to design aspects of the canister.

The issues of concern with canister design are criticality control and overpressurization protection. With respect to criticality control, this evaluation shows that the canister will remain subcritical under any configuration or following structural deformation due to a load drop. With respect to overpressurization protection, two relief valves will be installed on each canister to prevent the possibility of a single failure or common mode failure from overpressurizing the canister. Thus, it can be concluded that the design of the defueling canisters neither increases the probability of any accident previously evaluated nor creates the possibility of a different type of accident. Additionally, as the current TMI-2 Technical Specifications do not specifically address containment of the fuel debris, the margin of safety as defined in the basis of the Technical Specifications is not reduced.

As discussed above, these canisters are critically safe by design. Additionally, activities associated with canister closure and handling, including installation of the relief devices, will be performed in accordance with procedures prepared, reviewed and approved in accordance with TMI-2 Technical Specifications Section 6.8, which requires NRC approval of certain types of procedures. Therefore, as no further engineering controls are needed to ensure criticality safety and activities associated with canister closure and handling will be controlled in accordance with procedures subject to Technical Specification Section 6.8, it is GPU Nuclear's belief that no changes to the Technical Specifications are required.

In conclusion, within the bounds described in this report, the design and use of the defueling canisters do not result in an unreviewed safety question, nor require changes to the TMI-2 Technical Specifications.

6.0 CONCLUSION

Canisters are needed to provide effective long term storage for the TMI-2 core debris. Three types of canisters are required to support the defueling system: fuel, filter and knockout canisters. These canisters have been evaluated to determine if they could safely perform their function under normal and accident conditions. The results of this evaluation show that the canisters will remain subcritical under normal operations, handling and accident conditions. A structural evaluation of the canisters has shown that they maintain their integrity and will function as designed under normal operating conditions. Drop analyses and drop tests were used to determine the effect of a design basis drop on the canister shell and internals. The results from these analyses were used in determining the reactivity of the canisters under accident conditions. Therefore, based on structural and criticality considerations, it can be concluded that these canisters can safely function under normal and accident conditions at TMI-2.

7.0 REFERENCES

1. TMI-2 Defueling Canisters Final Design Technical Report, Babcock and Wilcox, Document No. 77-1153937-05, dated March 28, 1986.

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6. "NULIF-Neutron Spectrum Generator, Few Group Constant Calculator and Fuel Depletion Code", BAW-426, Revision 5.

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10. TMI-2 Drop Testing of Defueling Canisters Final Report, Babcock and Wilcox, Document No. 77-1156372-00, February 1985.

11. TMI-2 Early Defueling Fines/Debris Vacuum System Proof-of-Principle Test Report, TMI-AD-84-018, Westinghouse Electric Corporation, Advanced Energy Systems Division, October 1984.

12. Criticality Safety Evaluation for Coagulants, GPU Nuclear letter 4410-87-L-0021, dated February 20, 1987.

13. Safety Evaluation Report for Canister Handling and Preparation for Shipment, 4350-3256-85-1, Revision 4.

14. Design Engineering Memorandum DEOE-1330, dated August 28, 1987, "B&W Fuel Canister Load Drop Testing."

15. Filter Canister Media Modification, GPU Nuclear letter 4410-87-L-0092, dated June 10, 1987.