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Fuel Sorting Evaluation

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Abstract: An evaluation of functions and requirements associated with sorting fuel from the Hanford K Basins is presented to support design issue resolution decisions for achieving interim fuel storage. Potential requirements satisfied by fuel sorting are identified and a subset of these requirements are recommended for implementation in design activities. The recommendations are provided as input to a management decision process where decisions are finalized and the sorting issue is closed.

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FUEL SORTING EVALUATION

EXECUTIVE SUMMARY

The following fuel sorting evaluation was completed to recommend fuel sorting functions and requirements incorporated into the Spent Nuclear Fuel Project. The evaluation supports resolution of Issue 168 in the Technical Issues Management Database. Based on the current design concepts, fuel sorting during fuel retrieval from the basins is the final opportunity to adjust the attributes of fuel combined in a Multi Canister Overpack (MCO). Therefore, the sorting evaluation considered the potential for requirements to be imposed by each SNFP Sub-Project interfacing with a loaded MCO. The result is identification of all known sorting requirements for the SNFP.

The sorting evaluation was initiated by assembling a task team with members representing sub-projects interfacing with a loaded MCO. These interfacing sub-projects included Fuel Retrieval, Multi Canister Overpack, Cask and Transportation, K Basin Vacuum Drying, Canister Storage Building, Conditioning, and General Areas which cross cut sub-projects (e.g., criticality, accountability, etc.). Potential fuel sorting requirements were compiled from each sub-project and reviewed by the task team. The task team review determined if,

- fuel sorting had a primary influence on satisfying the potential requirement (if not, dropped from further consideration as a sorting requirement),
- an alternative to fuel sorting was available for satisfying the potential requirement, or
- fuel sorting was the only method for satisfying the potential requirement.

Schedule requirements for the Spent Nuclear Fuel Project require that a recommendation on fuel sorting be provided based on incomplete data. The recommendations which follow, if accepted, allows the project to proceed at risk. It was assumed that minimal fuel sorting requirements should be specified to minimize the potential for increasing operator dose and operational error. Therefore, only requirements which could not be satisfied by alternatives to sorting are included in the recommendation. However, limiting fuel sorting in this manner implies accepting that an alternative to fuel sorting, where available, will be pursued to satisfy some project requirements.

The evaluation results recommend including a fuel sorting function in the fuel retrieval systems. The recommended requirements satisfied by the fuel sorting function are as follows:

- Mk 1A fuel must be placed in the baskets designed with a larger central void for criticality control (this requirement does not preclude the option of placing some shorter Mk IV elements in baskets with Mk 1A elements),
- Single Pass Reactor (SPR) fuel should be placed in shorter fuel baskets and possibly loaded separately into MCO(s) to allow segregated processing of SPR fuel, and
- Element sorting to differentiate elements included in the MCO inventory by piece count data from elements inventoried by weight.

Additional sorting factors were identified with the potential to become sorting requirements in the future. These factors, requiring additional study prior to defining as a requirement, are as follows:

- Sorting to direct partial elements to a scrapholder or fuel basket such that efficient utilization of a MCO is achieved, and
- Element sorting to ensure fuel baskets are loaded with elements which approach the geometries analyzed by the criticality analysis.

It is recommended that other potential sorting requirements associated with narrowing the variability of heat generation rates produced by MCOs and reducing the number of MCOs which may need conditioning not be included as a fuel sorting requirement at this time.

Data are not available to specify if some of the identified sorting factors should be included as system design requirements. The following additional studies are recommended to provide for detailed definition.

- Development of a definition for an intact element to determine if piece count data or weighing is used for accountability,
- Development of a scrapholder design concept followed by a trade study defining the partial element length which should be placed in a scrapholder for efficient MCO utilization,
- Completion of documenting currently available criticality analyses,
- Development of a practical definition for fuel geometries which comply with the MCO criticality analysis bounding conditions

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FUEL SORTING EVALUATION

1.0 INTRODUCTION

This report was prepared to support resolution of Issue 168 in the Technical Issues Management Database for the Spent Nuclear Fuels Project (SNFP). The purpose of this document is to identify if fuel sorting is needed and recommend an approach for sorting the Spent Nuclear Fuel (SNF) in the K Basins based on potential requirements identified to support the fuel retrieval through interim storage systems of the SNFP. The scope of the evaluation included consideration of process elements within the Fuel Retrieval, Multi-Canister Overpack, Vacuum Drying, Canister Storage Building, and Conditioning Sub-Projects which may require implementation of a fuel sorting scheme to successfully support the interim storage of fuel from the K Basins. The evaluation will identify requirements potentially influenced by fuel sorting, identify fuel sorting criteria which would satisfy those requirements, identify and evaluate the potential for alternatives to satisfy those same requirements, and develop an overall recommendation for fuel sorting criteria which should be implemented in design efforts. The result is the identification of all currently known sorting requirements for the SNFP.

2.0 BACKGROUND

The K East (KE) and K West (KW) Basins store SNF in three types of canisters (Marks 0, I, and II). There are 3666 canisters containing 50,683 fuel assemblies in KE Basin and 3815 canisters containing 52,959 fuel assemblies in KW Basin (WHC 1995a). KW Basin contains four types of fuel (N Reactor fuel types Mk 1A, Mk IV, Mk IVB, and Single Pass Reactor (SPR) fuel), while KE Basin contains three fuel types (N Reactor fuel types Mk IV, Mk IVB, and SPR fuel). The SPR fuel can be visually distinguished from the N Reactor fuel types based on distinctive design differences. However, N Reactor fuel types are sufficiently similar in appearance (element inside and outside diameter differences range from 0.05 to 0.18 cm) to preclude distinction using visual observation alone. Identification of the Mk 1A fuel type can have implications in the development of designs which must maintain criticality controls, as the Mk 1A outer element was fabricated from uranium with an enrichment of 1.25 Wt% ^{235}U , while the inner element contains 0.947 Wt% ^{235}U . Mk IV and Mk IVB assemblies contain inner and outer fuel elements fabricated from uranium enrichments of less than or equal to 0.947 Wt% ^{235}U .

A variety of N Reactor fuel element lengths were produced and are stored in the K Basins. Mk IV fuel element lengths range from 44.2 cm to 66.3 cm while Mk 1A element lengths range from 37.8 cm to 53.1 cm (WHC 1995a). Therefore, length could be considered as an attribute for differentiating between Mk 1A and most of the Mk IV fuel.

N Reactor fuel within each fuel type has been subjected to exposures ranging from 0 to 3600 MWD/MTU and discharged over a 16 year period (January 1971 to April 1987) creating fuel with a range of radionuclide compositions (WHC 1995a). This radionuclide composition range also translates into a variation in the heat generation rate from groups of fuel elements within each fuel type.

SPR fuel is currently stored in both basins. The length of SPR fuel elements range from approximately 12 cm to 23 cm, with specific lengths generally associated with enrichment ranges. The element diameters range from approximately 3.45 cm to 3.63 cm (WHC 1995a).

There are 3.38 MTHM of SPR fuel at Hanford. The majority of SPR fuel is 2.88 MT of highly depleted uranium contained in 779 fuel elements which have recently been transferred from PUREX to the KW Basin. The remaining 0.5 MT of SPR fuel is natural or enriched uranium contained in 185 elements located in KE (0.4 MT in 138 elements) and KW (0.1 MT in 47 elements) Basins. The KE Basin fuel is currently stored in 3 canisters and 2 baskets. The transfer of SPR fuel to canisters in KW Basin was incomplete at the time this report was prepared. However, it is estimated SPR fuel will be stored in approximately 22 canisters in KW Basin when the transfer is complete.

The physical condition of stored fuel elements also varies within the basins. Some of the stored fuel elements have cladding breaches which allows the initiation of corrosion reactions between the uranium metal core and the storage basin water. The reactions potentially produce corrosion products within the fuel element cladding or adhering to the fuel surface which can interfere with processes transferring fuel to dry interim storage. An underwater visual survey of fuel in the KE Basin was conducted in 1994 as part of fuel characterization activities. The visual survey concluded that over 90% of the loaded canisters in KE Basin contain at least one breached fuel element. It was further estimated that approximately 27% of all inner elements and 42% of all outer elements stored in KE Basin are breached to some extent (WHC 1995a). The extent of fuel reaction varies within the KE Basin fuel elements, ranging from a break or opening in the cladding-to-end cap braze area to reactions sufficient to swell fuel and split cladding. Void spaces within the cladding where a significant portion of the uranium fuel core has been removed can be observed for some elements. Extensive visual survey data of KW Basin fuel is not available. Each storage canister includes a lid for isolation of the fuel from the basin water preventing simple visual surveys. However, selected canisters (three) have been opened to obtain fuel samples as part of characterization activities. Observations from this limited number of canisters suggest fuel corrosion in the KW Basin should not be expected to be as extensive as that observed in the KE Basin visual survey.

The variations described above indicate potential fuel sorting schemes could be proposed to group fuel based on a number of different attributes. The Integrated Process Strategy (WHC 1995b) transfers fuel from the basins to dry interim storage based on placing fuel in a Multi-Canister Overpack (MCO) at the basins. No allocation has been made to routinely reopen the MCO and

redistribute fuel once it is placed in an MCO and the shield plug welded in place. Fuel sorting during the fuel retrieval activities in the basins is the final opportunity to adjust the attributes of fuel combined to be packaged in an MCO. Therefore, an evaluation of fuel sorting must consider the potential requirements for each SNFP sub-project which interfaces with the loaded MCO. These sub-projects, as identified in WHC 1995c, are:

- Fuel Retrieval - performs any potential canister or fuel sorting activities and loads the MCO fuel baskets
- Multi-Canister Overpack - procures MCOs and welds shield plug on loaded MCO
- Cask and Transportation - procures MCO transport cask, moves loaded MCO from basin to vacuum drying, and transports loaded MCO from 100 Area to Canister Storage Building
- K Basin SNF Vacuum Drying - dries fuel in a loaded MCO to a condition allowing transport to and staging in the Canister Storage Building
- Canister Storage Building - provides staging and interim storage of a loaded MCO
- Conditioning - conditions fuel in a loaded MCO and seals the MCO allowing transfer from staging to interim storage.

3.0 FUEL SORTING EVALUATION

A definition of fuel sorting was established prior to development of a fuel sorting evaluation. Two general types of sorting are available within the K Basins based on the fuel storage configuration. These alternatives are:

- Fuel Element Sorting - This type of sorting is based on examining or measuring each element for some attribute which forms the basis for directing the element to a subsequent processing path.
- Fuel Canister Sorting - This type of sorting is possible by relying on the safeguards accountability records to identify location and characteristics of fuel keys (groups of fuel elements discharged on the same day), selecting the fuel from groups of canisters, and placing fuel in a single MCO to achieve a desired product characteristic. The product characteristic in this case would be calculated from the fuel records data and confirmed on an individual MCO basis rather than examining each fuel element.

A third type of physical sort is possible from the system configuration and that is by fuel basin. However, the process systems under consideration

will naturally maintain KE Basin fuel sorted from KW Basin fuel. Therefore, unless a need is identified to mix fuel from separate basins, sorting by basin will be assumed throughout the evaluation which follows.

3.1 EVALUATION METHODOLOGY

The evaluation of fuel sorting was developed by assembling a task team which included members from a range of sub-projects. Based on input from the team members, each major sub-project area down stream of a fuel sorting step was considered to identify requirements with the potential to be influenced by some type of fuel sorting. A criteria description was developed for each requirement which might be satisfied by a fuel element sorting scheme. Alternatives to fuel element sorting were also proposed as methods for achieving the requirement which could range from fuel canister sorting to facility design modifications.

The task team reviewed the consolidated information which resulted in the 21 potential requirements provided in Appendix A. The requirements were initially evaluated to identify those that could be eliminated from further consideration based on fuel sorting providing only a secondary influence on satisfying the requirement. The remaining requirements were then discussed, focusing on the proposed fuel element sorting criteria and alternatives to arrive at a group of requirements which could only be satisfied by fuel element sorting. Table 1 provides a summary of the requirements influenced by fuel or canister sorting which were determined to be resolved only by fuel element sorting. Table 1 also includes the requirements that could be satisfied by fuel element or fuel canister sorting where no alternative to some type of sorting could be proposed. Fuel canister sorting is recommended over fuel element sorting where feasible. Table 2 provides a summary of the requirements which could be achieved by fuel sorting, but had alternative methods to satisfy the requirement which did not involve sorting. The alternative considered viable is underlined in the comment column of Table 2.

3.2 DISCUSSION

The evaluation of fuel sorting was based on the concept that from a basin operations view point fuel element sorting activities should be minimized to minimize the complexity of activities which must be performed within the basin pool to minimize operator exposure. This competes with all requirements that could be potentially achieved by fuel element sorting and leads to a preference to only consider fuel element sorting when no other alternative is available to successfully remove the basin fuel. Canister sorting was not viewed as being as significant as fuel element sorting to increasing operator

Table 1. Identified Requirements Needing Fuel Element or Fuel Canister Sort to Satisfy

Requirement	Fuel Element Sorting Criterion to Satisfy Requirement	Comments/Alternative to Use of Fuel Sorting
REQUIREMENTS SATISFIED ONLY BY A FUEL ELEMENT SORT		
Fuel geometry must approach the cylindrical array geometry used in the criticality analysis to be placed in a fuel basket. Otherwise it must be placed in a basket located in the end of a MCO to take advantage of neutron leakage.	Sort intact, nearly intact and element pieces that can be placed in a fuel basket to form stacked pieces to approach a geometry in the current criticality analysis from those which must be placed in an end basket.	Alternative criticality analysis cases could be pursued to broaden the geometry assumptions defining the element which can be placed in a central fuel basket. This would refine the sort criteria, but not change the need to sort.
Satisfy recommended safeguards accountability plan requiring production of a MCO inventory of nuclear materials using piece count inventory data or weighing, depending on an element approaching an intact condition.	Sort fuel elements/pieces based on approach to an intact element to identify those which can be placed in the MCO inventory using piece count data or must be weighed for inventory.	
Minimize number of MCO's required to be procured by MCO Sub-Project by maximizing use of fuel loading positions. Total MCOs upper limit of 440 based on available CSB positions.	Segregation of short element pieces for placement in a scrapholder based on a length which produces efficient utilization of the MCO.	Assumes partial elements shorter than a specified length in a scrapholder provides more effective use of MCO space. Requires a scrapholder design concept to define.
REQUIREMENTS SATISFIED BY A FUEL CANISTER SORT		
Limit heat generation to a specified maximum or to within a known range for each MCO to provide sufficient margin to prevent excessive water-uranium reactions at elevated fuel temperatures.	Sort fuel to achieve a heat generation rate in each MCO to be within a specified range.	May be accomplished by canister selection planning.
The fuel temperature maintained at less than 400 deg F during storage to satisfy current CSB performance specification.	Sort fuel to achieve a heat generation rate in each MCO to be within a specified range.	May be accomplished by canister selection.
Minimize the number of MCOs containing single pass reactor fuel.	Sort to place aluminum clad fuel in separate MCO(s) to allow handling under special procedures.	Accomplished by canister selection.
Maintain MCO fuel configuration in critically safe geometry throughout processing and storage period.	Sort fuel assemblies in KW Basin by length and place all fuel at less than 55 cm in Mk 1A baskets.	Criticality safety required to be addressed in all phases. Alternative to element sort is to assure all intact Mk 1A in KW Basin are placed in baskets with central void core by placing all fuel from octagonal top canisters in Mk 1A baskets or sort by canister records. Relies on proper canister loading and records at time of fuel discharge.

Table 2. Identified Requirements Satisfied by Alternatives to Sorting

Requirement	Fuel Sorting Criterion to Satisfy Requirement	Comments/Alternative to Use of Fuel Sorting
Fuel cleaned during Fuel Retrieval to meet a specified cleanliness criterion to allow vacuum drying to remove sufficient water from an MCO at a 50 deg C operating temperature to maintain the MCO below its design pressure throughout the range of environmental conditions selected for design to comply with the transport and staging safety boundaries. One method translates this to limiting the quantity of water available to vaporize and react with uranium at bounding shipping and staging temperatures.	Sort elements by examination of each element to identify if additional cleaning is required. Requires development of a measurable attribute which can be related to the residual water remaining after vacuum drying at 50 deg C. Example of this is limiting the quantity of sludge remaining on fuel element which is translated to a quantity of bound water by drying curve data.	Alternative would increase vacuum drying temperature to upper bound MCO temperature under normal shipping conditions (75 C) as the mechanism for controlling pressurization during shipping. Monitoring and venting in the CSB would be used to control pressurization during staging. This would be expected to convert the degree of sludge removal from a parameter measured to show compliance with a safety boundary to a mechanism for increasing vacuum drying throughput.
Fuel basket from Fuel Retrieval balanced for insertion in MCO with minimum of special tools or procedures.	Distribute fuel by length for basket to hang within a specified approach to plumb. May also be accomplished by canister selection planning.	Design of a handling tool for basket insertion.
Limit the maximum reacting surface area entering K Basin Vacuum Drying in a MCO during conditions when oxidant limitations are not available to control the potential for excessive water-uranium reaction rates.	Sort fuel to achieve a specified number of failed elements per MCO. May result in a criterion restricting the number of elements with exposed fuel plus scrap in a MCO. Potentially accomplished by weight comparison to determine presence of extensive intergranular corrosion or measurement of hydrogen or Kr generation rate for comparison with a known standard.	Alternative criterion could require exposed fuel plus scrap to be within a calculated range to avoid high grading initial MCOs, then not be able to load significant quantities of fuel in MCOs near the end of operations (i.e., concentrating good fuel also concentrates bad fuel). Alternatively, design vacuum drying to accommodate the worst case reacting surface area.
Maximize removal of water in K Basin Vacuum Drying by draining and bulk removal prior to vacuum drying to minimize cycle time and duration that fuel is exposed to water vapor with significant water inventory in MCO.	Sort fuel with damage on one end to be oriented in a basket to promote drainage, depending on the element condition or physically modify cladding of fuel with potential to trap water during draining, based on visual observation.	Increase vacuum drying to accommodate reduced throughput of an individual station based on assuming some elements have been oriented to trap free water in a damaged end.
Provide a minimum or known range of heat generation in each MCO to provide sufficient heat source to attain vacuum drying operating temperature within cycle time allocation.	Sort fuel to achieve a heat generation rate in each MCO to be within a specified range. May also be accomplished by canister selection planning.	Design MCO heating system to allow for drying MCOs with minimal heat load.
Minimize the number of MCOs which require processing by the conditioning system.	Sort elements such that some MCOs can satisfy interim storage criteria after cold vacuum drying.	Dependent on final results of trade studies identified in MCO venting evaluation. Potential to be based on canister sort. Alternative is to plan on conditioning all MCOs.

exposure, since the piece count involved reduces from approximately 200,000 elements to approximately of 7,000 canisters.

3.2.1 Requirements Needing Fuel Element Sorting Support

Three requirements were identified in the sorting evaluation which could be accomplished only by fuel element sorting as indicated on Table 1. The requirements are related to MCO utilization, support of safeguard accountability plans, and ensuring compliance with the criticality analysis developed for the MCO design. Conceptually, minimizing the number of MCOs produced will reduce near term and future costs for interim storage and future disposition of fuel. Quantification of this cost incentive has not yet been documented. However, there is an upper bound requirement driving effective utilization of each MCO embedded in the CSB performance specification limiting the total MCOs for all fuel and scrap storage to 440 MCOs. This upper bound assumes utilization of all vault storage tubes without maintaining a reserve of empty storage tubes for MCO overpacks.

Fuel sorting support for effective MCO utilization involves determining a cut off length for a partial element which should be placed in scrap holder or utilize a position in a fuel basket which would otherwise be available for longer fuel pieces. While other methods could be devised during design, one approach to this type of fuel element sorting would be to visually gage the length of each element against a go/no-go standard.

Support for safeguards accountability plans require a determination as to the extent element piece count data can be used for construction of each MCO inventory (WHC 1995f). This requires evaluating each element against a standard (not yet specified) to determine if the element can be considered intact from a safeguards perspective. Intact elements will be incorporated in the MCO inventory based on piece count data. Elements and pieces which are not sufficiently intact to use piece count data must be incorporated in the MCO inventory by a weight measurement. This identification process could be considered a form of sorting, however, the need to physically place the fuel in a specific basket based on accountability data requirements will depend on the weighing method developed during design.

The MCO criticality analysis currently relies on the fuel element geometries placed in a fuel basket loaded in center positions of the MCO approach the ideal configurations analyzed. Fuel elements which significantly depart from the ideal geometries must be located in a basket loaded on the end of the MCO in order to provide additional neutron leakage for criticality control margins. This indicates there will exist a requirement that fuel elements be evaluated to determine whether an element must be placed in a basket loaded on the end of the MCO. The criticality analysis completed to date is based on fuel elements approaching a right cylinder geometry, with the cylinder circumference intact.

The system analyzed is currently under moderated such that inclusion of partial elements in a fuel basket increases the water (moderator) in the fuel array, increasing the system reactivity. Mk 1A elements have been analyzed as complete assemblies, requiring that the outer element be paired with an inner element to reduce the system reactivity. Each of these attributes contribute to the sorting criteria which indicate whether a fuel element must be loaded in an end fuel basket. Specific definition of the sorting criteria could potentially be modified by a broader criticality analysis than has been completed to date.

3.2.2 Requirements Needing Canister Sorting Support

Four additional requirements indicated on Table 1 were identified that could be achieved by fuel canister sorting. Criticality control appears to be reasonably achieved by canister selection (applicable to KW Basin only). This sort is required in order to ensure that Mk 1A fuel is placed in the fuel basket designed with a larger central void area to maintain criticality control during processing and storage. This approach does rely on records of canister loading and position, however there is no known reason to question these data at this time.

A separate fuel basket design has also been developed for SPR fuel which allows stacking of 10 baskets for the shorter fuel in a single MCO for efficient utilization. In addition, uncertainty exists as to the specific processing conditions which will ultimately be defined for the single pass reactor fuel. At this time, the potential exists for this fuel to require different conditions than the N Reactor fuel due to the difference in cladding material. To support this potential and efficient MCO utilization, the single pass reactor fuel must be segregated in a separate MCO(s). Sorting to achieve this can be accomplished by selection of canisters as current records indicate that N Reactor fuel and single pass reactor fuel have not been mixed together in storage canisters.

Two additional requirements were identified related to controlling the heat generation rate of each MCO within a specified range. A decision to actually implement this criterion appears to be amenable to deferral at this point in time as designs are proceeding assuming bounding heat generation rates. Implementation of fuel canister selection could be considered at a future date and is a mechanism to provide additional conservatism that operations will always be within the design envelope of systems, or be used to resolve a currently unforeseen design problem which may arise from using the current bounding heat generation rates.

3.2.3 Requirements with Alternatives to Sorting

Six requirements were identified in Table 2 which could be achieved by a fuel sorting methodology, but alternatives are available to satisfy the requirement which do not involve either fuel element or canister sorting. The first of these types of requirements involves defining an objective for the fuel cleaning step which is included in the Fuel Retrieval activities.

The initial concept of fuel cleaning was to reduce the quantity of sludge and fuel corrosion products adhering to the external surfaces of fuel elements to reduce the quantity of bound water transferred into an MCO. This bound water is currently assumed to remain in the MCO after vacuum drying, until the fuel has been conditioned (during transport to the CSB and while staged within the CSB). Unfortunately, drying data for actual sludge and fuel corrosion products will not be available for some time. This requires extrapolation of the sludge drying properties from materials hypothesized to be similar, a method which inherently contains considerable uncertainty. A total water limit approach has been used as the method restricting the maximum pressure that could be generated in the MCO. This has the effect of requiring a fuel element sort based on the apparent quantity of residual sludge to identify if more aggressive cleaning is needed. The approach makes a determination of the residual sludge in each MCO process control data required to verify that fuel transport and staging is being performed within the design safety envelope.

An alternative to this approach would rely on increasing the operating temperature of the vacuum drying system to reflect the maximum design cask temperature during transport under normal conditions (75 C) (WHC 1995e). Performing vacuum drying at this temperature would then be the basis for preventing evolution of additional water vapor from contained sludge during transport and would eliminate that as a uranium reactant source. Monitoring and venting would be relied upon to control MCO pressurization during staging in the CSB where fuel temperatures could increase to 200 C. This approach decouples fuel cleaning from performing a function associated with maintaining operations within the design safety envelop. However, fuel cleaning would still be desirable to reduce the time required for vacuum drying operations to achieve equilibrium water removal. The degree of fuel cleaning then becomes a process optimization parameter which can be performed on a best effort basis without a direct verification method beyond determining that fuel cleaning vigilance must be improved if vacuum drying cycles start to become unreasonable to meet production requirements.

Fuel element sorting could be used to distribute fuel by length around an MCO basket such that the free hanging basket is sufficiently close to plumb that it can be inserted in an MCO without the aid of special tools. The alternative to this approach would be to provide tools to aid in the MCO basket insertion that widens the tolerance band around hanging plumb such that sorting for this parameter is not required.

Fuel element sorting could be used to attempt to limit the reacting fuel surface area in an MCO prior to introduction into vacuum drying. This would be achieved by measuring the hydrogen or ^{85}Kr generation rate from a fuel element for comparison with a standard that has been developed from experimental data. A more practical variation of this sorting would be to perform the measurement on a basket of fuel or MCO filled with fuel. Excessive reaction rates would indicate that some, or all of the fuel elements contained in the measure fuel group would need to be recycled through the fuel cleaning station or addressed by special cleaning methods to reduce the reacting surface area. An alternative to this approach is to ensure the vacuum drying system design envelop is broad enough to accommodate the worst case reacting surface area, or develop a special drying procedure similar to that required for scrap.

Fuel element sorting could be used to identify fuel with damaged ends that could trap bulk water within the residual cladding. In its simplest form, the damaged ends could be oriented down in the fuel basket to promote drainage of bulk water. More complex damage patterns could require physical modification of the residual cladding to promote water drainage which would entail routing the identified fuel elements through a special fuel preparation line. An alternative to this type of sorting is to increase the vacuum drying time based on assuming some elements contain water which does not drain. This may result in an increase in the number of drying stations.

Fuel element or canister sorting to achieve a known heat generation rate range for each MCO could be used as an alternative to provide a minimum heat generation rate in support of vacuum drying heatup. This can also be accomplished by sizing the vacuum drying heating system to accommodate the required cycle time assuming no heat generated by the MCO.

Fuel element or canister sorting based on the surface condition of fuel elements has been proposed as a method to reduce the quantity of fuel requiring conditioning prior to insertion into interim storage. This concept is under evaluation as part of a study of alternatives to MCO venting during staging in the CSB. At this time, designs are proposed to proceed assuming all MCOs will be conditioned prior to placing in interim storage (WHC 1995g).

4.0 RECOMMENDATION

Schedule requirements for the Spent Nuclear Fuel Project require that a recommendation on fuel sorting be provided based on incomplete data. The recommendations which follow, if accepted, allows the project to proceed at risk. The evaluation identifies concerns that could be satisfied by fuel sorting, but had alternatives that could be proposed. Since operator exposure is likely minimized by minimizing activities in the basin, it is recommended that designs proceed assuming the requirements in Table 2 above are pursued by the alternatives similar to those presented in the evaluation. This includes

a best effort washing or mechanical cleaning of each fuel element to minimize fuel corrosion products and sludge added to the MCO. However, a quantitative measure of the residual sludge would not be required, assuming proposed modifications to vacuum drying and staging systems are implemented. It should be noted that acceptance of the a recommendation which limits the requirements satisfied by fuel sorting must at the same time accept that these other concerns will be pursued by an alternative method. If further design efforts indicate the proposed alternatives are impractical, additional sorting criteria would need to be developed for inclusion in the design. The following represents the recommended fuel sorting functions and requirements for the SNFP based on the data available at this time.

4.1 SPECIFIC FUEL SORTING RECOMMENDATIONS

1. A fuel sorting function should be included in the Fuel Retrieval system design criteria.

Basis: The recommended path for design activities at this time is to assume a combination of fuel element sorting, fuel canister sorting, and alternatives to sorting to address the requirements identified in this study as potentially resolved by sorting. The evaluation described in Section 3.0 identified a number of requirements which could only be satisfied by sorting both fuel elements and fuel canisters. It is unlikely that new concepts can be developed for satisfying all of these requirements to eliminate the need for some fuel sorting.

2. A requirement to perform fuel canister sorting is recommended to ensure the Mk 1A fuel in KW Basin is loaded in the proper design MCO basket.

Basis: This requirement originates from the criticality analysis for the MCO design. A MCO design concept has been selected which uses a central void core to maintain criticality control of the higher uranium enrichment of Mk 1A fuel when placed in the fuel basket array (WHC 1995d). The central void core is not required for criticality control of Mk IV fuel and separate basket designs have been developed for each fuel type in order to maximize fuel element loading in an MCO. The separate basket designs require that Mk 1A fuel be loaded in the proper design of basket. However, this requirement does not preclude the option of placing shorter Mk IV elements in baskets with Mk 1A elements.

3. A requirement to perform fuel canister sorting is recommended to segregate MCOs containing SPR fuel from MCOs containing N Reactor fuel.

Basis: This requirement provides for efficient utilization of the MCO by placing the SPR in shorter baskets, commensurate with the shorter SPR fuel length. The segregation also supports a projection that unique processing conditions will need to be developed to dry and condition the aluminum clad

SPR fuel (undocumented). Development of these conditions has not been initiated due to the small quantity of SPR fuel which must be processed. It is unlikely that development of the SPR fuel processing conditions will be initiated until after much of the sub-project design activities are complete.

4. A requirement to perform fuel element sorting is recommended for differentiating between elements incorporated into the MCO inventory by piece count data or weighing.

Basis: The nuclear material accountability plan recommends construction of the nuclear material inventory loaded in each MCO from existing basin accountability data (WHC 1995f). This is proposed to be accomplished for essentially intact elements by transfer of existing data for each canister to the specific MCO for construction of inventory data. The recommended nuclear material accountability plan relies on application of existing piece count data to the maximum extent possible for intact or nearly intact elements, but requires determining a weight of all pieces added to the MCO that can not be considered a full element. Development of a criterion defining the approach to a complete element which allows use of the piece count data is not currently available to provide a specific sorting criterion.

5. A requirement to perform fuel element sorting to determine if an element or assembly is long enough to be loaded in a fuel basket position or placed in a scrapholder, should not be incorporated in current design activities at this time.

Basis: The CSB Performance Specification limits the total number of MCOs to 440. The potential exists for this maximum total to be reduced if it is determined that CSB vault tube positions must be reserved for MCO overpacks. Current estimates of the MCOs generated during removal of fuel from K Basins is 398, allocating 54 baskets for scrapholders. In addition, minimizing the number of MCOs produced is projected to minimize near term and future disposition costs (undocumented). The limited CSB capacity available for increasing the total of MCOs could result in this factor becoming a sorting requirement in the future. However, a firmer concept description of the scrapholder design is required to specify the length used as a sorting criterion to determine when fuel pieces are placed in a scrapholder for efficient MCO utilization. The second study in Section 4.2 must be completed to establish if this type of sorting is required.

6. A requirement to perform fuel element sorting to identify whether fuel can be loaded in a fuel basket which can be located at any position within the MCO or must be included in a basket positioned in the end of a MCO to satisfy the MCO criticality analysis should not be incorporated in current design activities at this time.

Basis: While the MCO criticality analyses is not completely documented, the available analysis indicates that a decision point potentially exists for determining if an element approaches the analyzed geometries to allow loading in a fuel basket which is located in a central position of the MCO. Fuel

elements which significantly depart from the analyzed geometries must be placed in a fuel basket positioned on the end of a MCO to take advantage of additional neutron leakage to maintain the required criticality control margins. The current analysis is based on the central MCO fuel baskets containing cylindrical shaped fuel assemblies and assumes Mk 1A assemblies must contain an inner element. This definition is not considered specific enough for actual implementation and a parametric study of the criticality analysis will be required to define a practical sorting criterion on fuel geometry. The third and fourth studies in Section 4.2 must be completed to establish if this type of sorting is required.

7. A requirement for fuel canister sorting or other actions directed toward narrowing the MCO heat generation variability should not be incorporated in current design activities.

Basis: It is recommended that designs proceed assuming no canister sorting in support of adjusting the heat generation rate of MCOs at this time, but to continue activities evaluating the ability to narrow this parameter during operations. Sub-project designs are currently proceeding based on the maximum predicted heat load in a MCO that could be experienced by filling a MCO with fuel elements containing the highest specific heat generation rate predicted to exist in the basins. Therefore, system designs will be able to accommodate SNFP activities without sorting to narrow the heat generation variability. However, canister sorting could provide additional margin during operation to ensure that MCOs generated are conservatively within the system design envelopes or provide a contingency that could be used to resolve currently unforeseen design problems that may develop during detailed design.

4.2 RECOMMENDED ADDITIONAL STUDIES

The following additional studies have been identified in the course of the evaluation which are required to allow specification of fuel sorting criteria in sufficient detail such that they can actually be implemented in the design process. These trade studies have not been included in the trade studies list presented in WHC, 1995c.

- Development of a clear definition of an intact element for the purposes of applying accountability piece count data in constructing the MCO inventory (Supports Recommendation 4, recommend assigning responsibility to the Fuel Retrieval Sub-Project as the definition may be dependent on the overall approach selected for implementing the recommended accountability plan).

- Develop the scrapholder design concept followed by a MCO volume utilization trade-off study to set a fuel length sorting criteria for placing a fuel piece in a fuel basket or scrapholder (Supports Recommendation 5, recommend assigning responsibility to the MCO Sub-Project).
- Complete documentation of current MCO criticality analysis (Supports Recommendation 6, recommend assigning responsibility to the MCO Sub-Project).
- Develop a practical definition of fuel loading geometries which meet the MCO criticality analysis bounding conditions. This could be accomplished by evaluating the impact of implementing the current MCO criticality analysis on fuel basket loading, or reevaluating the criticality analysis with non-ideal fuel geometry assumptions to identify if criticality control margins can be attained with less restrictive assumptions. (Supports Recommendation 6, recommend assigning responsibility to the MCO Sub-Project.)

5.0 REFERENCES

- WHC, 1995a WHC-SD-SNF-TI-015, (Rev 0), Compiled by SM Short and MM Beary, "Spent Nuclear Fuel Project Technical Databook", Prepared by Pacific Northwest Laboratory for Westinghouse Hanford Company, Richland, Washington.
- WHC, 1995b WHC-SD-SNF-SP-005, (Rev 0), "Hanford Spent Nuclear Fuel Project Integrated Process Strategy for K Basins Spent Fuel," Volumes 1&2, Westinghouse Hanford Company, Richland, Washington.
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6.0 ACKNOWLEDGEMENT

The following personnel participated in the task team assembled to evaluate the fuel sorting issue.

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Appendix A

Summary of Potential Requirements Considered for Influence by Fuel Sorting

Table A.1 Assessment of Potential Requirements Considered Influenced by Fuel Sorting (Sheet 2 of 5)

Activity	Requirement	Fuel Element Sorting Criterion to Satisfy Requirement	Comments/Alternative to Use of Fuel Sorting	Requirement Assessment
1. Fuel Retrieval	a) Minimize actions which increase equipment installation, number of operators, or time to produce a fuel basket in the basin, minimizing operator exposure.	Impose as few sorting criteria as possible.		
	b) Fuel cleaned during Fuel Retrieval to meet a specified cleanliness criterion to allow vacuum drying to remove sufficient water from an MCO at a 50 deg C operating temperature to maintain the MCO below its design pressure throughout the range of environmental conditions selected for design to comply with the transport and staging safety boundaries. One method translates this to limiting the quantity of water available to vaporize and react with uranium at bounding shipping and staging temperatures.	Sort elements by examination of each element to identify if additional cleaning is required. Requires development of a measurable attribute which can be related to the residual water remaining after vacuum drying at 50 deg C. Example of this is limiting the quantity of sludge remaining on fuel element which is translated to a quantity of bound water by drying curve data.	Alternative would increase vacuum drying temperature to upper bound MCO temperature under normal shipping conditions (75 C) as the mechanism for controlling pressurization during shipping. Monitoring and venting in the CSB would be used to control pressurization during staging. This would be expected to convert the degree of sludge removal from a parameter measured to show compliance with a safety boundary to a mechanism for increasing vacuum drying throughput.	A
	c) Maximize fuel cleaning throughput with a minimum of equipment installed in the basin.	Sort fuel visually to handle intact elements in one line, shunting unsound elements to another line allocated to use more cleaning time per element.	If multiple lines required, use both lines to handle elements as they come and utilize queuing to accommodate periods of higher and lower fuel cleaning throughput.	
	d) Fuel basket balanced for insertion in MCO with minimum of special tools or procedures.	Distribute fuel by length for basket to hang within a specified approach to plumb.	May be accomplished by canister selection planning or design of a handling tool for basket insertion.	A
2. MCO	a) Minimize number of MCO's required by maximizing use of fuel loading positions. Total MCO upper limit of 440 based on available CSB positions.	Visual segregation of intact elements from partial elements. NEED TO DEVELOP A DEFINITION OF SCRAP.	Assumes partial elements in scrap holder provides more effective use of MCO space.	S

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Assessment Codes:

A - Requirement can be achieved by an alternative to fuel element sorting. The alternative is adequate to achieve requirement and is qualitatively expected to be less expensive or result in reduced operator exposure.

S - Requirement can only be achieved by fuel element sorting.

X - Requirement is not readily influenced by fuel element sorting.

Table A.1 Assessment of Potential Requirements Considered Influenced by Fuel Sorting (Sheet 2 of 5)

Activity	Requirement	Fuel Element Sorting Criterion to Satisfy Requirement	Comments/Alternative to Use of Fuel Sorting	Requirement Assessment
3. Cask and Transportation	a) Maximum loaded cask with MCO constrained to 30 tons by capacity of basin cranes.	Sort fuel by length to load one basket per MCO with shorter fuel, reducing the fuel mass in each MCO.	May be accomplished by canister selection based on fuel records. Potential to reduce MCO length. Fuel sorting actions could have impacted the cask/transportation design if defined earlier.	X
4. K Basin Vacuum Drying	a) Limit the maximum reacting surface area in an MCO during conditions when oxidant limitations are not available to control the potential for excessive water-uranium reaction rates.	Sort fuel to achieve a specified number of failed elements per MCO. May result in a criterion restricting the number of elements with exposed fuel plus scrap in a MCO. Potentially accomplished by weight comparison to determine presence of extensive internal corrosion or ^{85}Kr generation rate for comparison with a known standard.	Alternative criterion could require exposed fuel plus scrap to be within a calculated range to avoid high grading initial MCOs, then not be able to load significant quantities of fuel in MCOs near the end of operations (i.e., concentrating good fuel also concentrates bad fuel). Alternatively, design vacuum drying to accommodate the worst case reacting surface area.	A
	b) Maximize removal of water by draining and bulk removal prior to vacuum drying to minimize cycle time and duration that fuel is exposed to water vapor with significant water inventory in MCO.	Sort fuel with damage on one end to be oriented in a basket to promote drainage, depending on the element condition or physically modify cladding of fuel with potential to trap water during draining, based on visual observation.	Increase vacuum drying to accommodate reduced throughput of an individual station based on assuming some elements have been oriented to trap free water in a damaged end.	A
	c) Provide a minimum or known range of heat generation in each MCO to provide sufficient heat source to attain vacuum drying operating temperature within cycle time allocation.	Sort fuel to achieve a heat generation rate in each MCO to be within a specified range.	May be accomplished by canister selection planning or design MCO heating system to allow for drying MCOs with minimal heat load.	A
	d) Limit heat generation to a specified maximum or to within a known range for each MCO to provide sufficient margin to prevent excessive water-uranium reactions at elevated fuel temperatures.	Sort fuel to achieve a heat generation rate in each MCO to be within a specified range.	May be accomplished by canister selection planning.	A

Assessment Codes:

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S - Requirement can only be achieved by fuel element sorting.

X - Requirement is not readily influenced by fuel element sorting.

Table A.1 Assessment of Potential Requirements Considered Influenced by Fuel Sorting (Sheet 2 of 5)

Activity	Requirement	Fuel Element Sorting Criterion to Satisfy Requirement	Comments/Alternative to Use of Fuel Sorting	Requirement Assessment
5. Canister Storage Building	a) Maximum individual MCO heat load less than 852 W per MCO to satisfy current CSB performance specification.	No sorting required to satisfy if fuel transfers started after 12/31/97.	If fuel transfer started prior to 12/31/97, older fuel keys can be selected based on records until after 12/31/97.	X
	b) Control the heat load of MCOs to produce a loading pattern which allows all fuel to be interim stored at approximately the same temperature.	Sort fuel to achieve a specified pattern of heat generation rates in the MCOs.	This is not the same as making the individual MCO heat load approximately constant. May be accomplished by canister selection. May also be accomplished by MCO sorting after a confirmatory measurement during vacuum drying.	X
	c) Allow placement of any MCO in any tube position within the CSB to simplify facility operations.	Sort fuel to approach a constant heat load in each MCO.	May be accomplished by canister selection to load an MCO from a mixture of keys.	X
	d) The fuel temperature maintained at less than 400 deg F during storage to satisfy current CSB performance specification.		May be accomplished by canister selection.	A
	e) Produce MCOs of known heat load to support CSB startup (heatup).		Accomplished by canister selection and possibly from data obtained during vacuum drying.	X
6. Conditioning	a) Minimize the number of MCOs which require processing by the conditioning system.	Sort elements according to cladding integrity attribute(s) (i.e., may indicate presence of hydrates and hydrides) such that some MCOs can satisfy interim storage criteria after cold vacuum drying.	Dependent on final results of trade studies identified in MCO venting evaluation. Potential to be based on canister sort. Alternative is to plan on conditioning all MCOs.	A
	b) Minimize the number of MCOs containing single pass reactor fuel.	Sort to place aluminum clad fuel in separate MCO(s) to allow handling under special procedures.	Accomplished by canister selection.	A

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Assessment Codes:

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S - Requirement can only be achieved by fuel element sorting.

X - Requirement is not readily influenced by fuel element sorting.

Table A.1 Assessment of Potential Requirements Considered Influenced by Fuel Sorting (Sheet 2 of 5)

Activity	Requirement	Fuel Element Sorting Criterion to Satisfy Requirement	Comments/Alternative to Use of Fuel Sorting	Requirement Assessment
7. General	<p>a) <u>Criticality Safety</u> - Maintain MCO fuel configuration in critically safe geometry throughout processing and storage period.</p> <p>a1) Ensure Mk 1A fuel placed in fuel baskets designed with central void core.</p> <p>a2) Fuel geometry must approach the cylindrical array geometry used in the criticality analysis to be placed in a fuel basket. Otherwise it must be placed in a scrapholder or basket located in the end of a MCO to take advantage of neutron leakage.</p>	<p>a1) Sort fuel assemblies in KW Basin by length and place all fuel at less than 55 cm in Mk 1A baskets.</p> <p>a2) Sort intact, nearly intact and element pieces that can be placed in a fuel basket to form of stacked pieces from those which must be placed in scrapholders or the scrap baskets.</p>	<p>Criticality safety required to be addressed in all phases.</p> <p>a1) Alternative to element sort is to assure all intact Mk 1A in KW Basin are placed in baskets with central void core by placing all fuel from octagonal top canisters in Mk 1A baskets or sort by canister records. Relies on proper canister loading and records at time of fuel discharge.</p> <p>a2) No alternative identified.</p>	A
	<p>b) <u>Accountability</u> - Satisfy recommended safeguards accountability plan requiring production of a MCO inventory of nuclear materials using piece count inventory data or weighing.</p>	Sort fuel elements/pieces based on approach to an intact element to identify those which can be placed in the MCO inventory using piece count data or must be weighed for inventory.		S
	<p>c) <u>Safety, Minimize Ignition Potential</u> -</p> <ul style="list-style-type: none"> Minimize material containing bound water (reactant that cold vacuum drying can not remove) Minimize material acting as potential ignition source (exposed hydride and metal fines) Bound at-risk respirable particulate loading in each MCO confirming it is within bounds used to define safety basis. 	Element by element sort criterion difficult to define.	Develop drying and storage process that can mitigate or preclude ignition events at maximum loadings. Develop a process that concentrates these problem fuel and handles these MCOs with special procedures or conditions. Measure the hydrogen or ⁸⁵ Kr generation rate from a fuel basket or MCO (fuel element grouping) for comparison against a known standard. Monitor drying curve during vacuum drying or conditioning to confirm particulate loading is within a specified bound.	X

Assessment Codes:

A - Requirement can be achieved by an alternative to fuel element sorting. The alternative is adequate to achieve requirement and is qualitatively expected to be less expensive or result in reduced operator exposure.

S - Requirement can only be achieved by fuel element sorting.

X - Requirement is not readily influenced by fuel element sorting.

Table A.1 Assessment of Potential Requirements Considered Influenced by Fuel Sorting (Sheet 2 of 5)

Activity	Requirement	Fuel Element Sorting Criterion to Satisfy Requirement	Comments/Alternative to Use of Fuel Sorting	Requirement Assessment
	d) <u>Safety, Minimize Accident Source Term</u> - Reduce the accident source term for an MCO which must be accommodated in safety analysis evaluations defining accident mitigation systems.	Sort fuel elements to levelize the quantity of key radionuclides in each MCO, reducing the peak source term which must be used in accident analyses. Primarily would level load the Pu-Am content which is approximated by levelized heat load.	Unlikely to significantly impact the accident source term by this method as failure to adequately sort could be considered an accident. Any actions to levelize the MCO heat load would likely have the effect of levelizing the source term.	X

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Assessment Codes:

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