# A Study of Transfer of UNF from Non-Disposable Canisters – 15388

Sven Bader *, Adam Howell *, Ernesto Faillace *
* AREVA Federal Services, LLC

## ABSTRACT

A study was performed by AREVA and URS for the Department of Energy (DOE) [1] to establish optimal methods for the opening of dry storage canisters (DSC) and the subsequent repackaging of used nuclear fuel (UNF) from the DSCs into generic standard transportation, aging, and disposal canisters (STADs) in wet or dry environments at reactor, consolidated storage, or repository sites. Eight dry and wet cutting technologies were evaluated: (1) skiving; (2) milling; (3) arc gouging/plasma torch; (4) cutting wheel; (5) diamond cable cutting; (6) laser cutting; (7) sawing; and (8) electrical discharge machining. The evaluated UNF repackaging technologies options included: (1) wet transfer in a pool; (2) dry transfer in a dry transfer system (DTS); (3) dry transfer in a fixed hot cell (FHC); (4) dry transfer in a mobile hot cell (MHC), and (5) a hybrid approach utilizing wet transfer in a pool and dry transfer in a FHC. A systems engineering evaluation was utilized for ranking the eight viable cutting options and the five different repackaging approaches for each of the sites. The systems engineering evaluation took into account six criteria (i.e., life cycle costs, worker dose, operational efficiency, technical maturity, ease of licensing, and waste generation) and performed a qualitative pairwise ranking of their relative importance to one another. Then quantitative or qualitative factors associated with each criterion (e.g., cost in millions of dollars, relative ease of licensing, etc.) for each option at each location (reactor, consolidated storage facility [CSF], repository) were developed based on historical experience, existing design studies, current "state-of-the art," and/or engineering judgment. Using this input, the systems engineering evaluation identified dry skiving as the preferred cutting technology, with the wheel cutting technology in either a dry or wet environment identified as a promising technology that, with some RD&D, could mature to a better option (depending also on the disposition of the used DSC). For a reactor and a CSF/repository site, the systems engineering evaluation ranked the repackaging option using the skiving dry cutting technique and wet transfer of UNF in a pool as the highest option. However for a CSF and a repository site, the team recommended the hybrid option using the skiving dry cutting technique and both dry and wet transfer of UNF in a pool and FHC as a potentially better option (providing specific benefits such as higher throughput and more flexibility in operation).

## INTRODUCTION

Since the mid-1980s, 8 cask vendors have provided approximately 12 cask systems comprising more than 30 different cask types, none of which have been considered for disposal in a geological repository. A variety of dry fuel storage systems have been, and continue to be developed and deployed with a trend moving to larger and larger canisters. Of the more than 70,000 Metric Tons Heavy Metal (MTHM) of UNF generated to date, approximately 28 percent is stored in more than 1,600 DSCs. The amount of fuel transferred from wet to dry storage is expected to increase to a rate of approximately 100 DSCs per year. The nuclear industry is currently using large dry storage systems with canister capacities of up to 37 pressurized water reactor (PWR) or 80 boiling water reactor (BWR) fuel assemblies to minimize the number of DSCs to be filled. These systems are either single purpose (storage only) or dual purpose (storage and transportation). None are currently licensed for disposal and potentially larger capacity DSCs may not be able to be emplaced in a geologic repository due to either physical emplacement constraints, the need for long periods of extended storage to allow for the thermal output of the fuel to decay so that repository thermal limits are met, or for other repository performance issues. Thus, in preparation of future disposal activities, there is the potential the UNF in these DSCs may have to be repackaged from larger to smaller canisters designed for disposal, STADs.

The DOE Office of Used Nuclear Fuel Disposition (UFD) sought input from industry [1] to develop a system for the repackaging of UNF currently stored in single and/or dual-purpose DSCs in the U.S. As part of this system, DOE UFD sought input on practical and efficient options for opening DSCs and the kind of fuel transfer system that could be implemented at reactor sites, a CSF, and a repository. To address this request, AREVA and URS utilized a systematic approach for ranking the viable repackaging options at each site, with particular emphasis on selecting a canister cutting technology and a repackaging approach with low worker doses, low life cycle costs, high operational efficiency, technical maturity, simple to license, and low waste generation. As some cutting and repackaging methods favor one criterion over another, a systems engineering (SE) evaluation was developed to effectively evaluate these trade-offs.

One of the major steps in repackaging involves the cutting of the lids and cover plates of DSCs prior to transfer of UNF to STADs. DSCs may be cut in a dry environment (e.g., skiving or milling) or in a wet environment (e.g., wheel-type cutting or electrical discharge machining). Overall, eight different cutting approaches were identified and subsequently evaluated for suitability of the cutting of the DSCs. General descriptions and important attributes are described for these eight cutting approaches.

In addition, four UNF transfer and repackaging technologies are described and evaluated for the transfer of UNF from a DSC to a STAD at a reactor site and a CSF/repository. These repackaging activities may also be performed in a dry environment (e.g., fixed hot cell at a repository) or in a wet environment (e.g., spent fuel pool). General functional requirements and major operational steps are described for each type of transfer and repackaging system, including the potential for scalability to achieve a throughput goal of 3,000 MTHM/yr at the CSF/repository.

These cutting and transfer technologies are combined into potential options for moving UNF from DSCs to STADs (e.g., dry cutting operation on DSC followed by transfer to a pool where UNF is transferred from the DSC to a STAD). After an initial screening of these potential options to remove those that were unfeasible, the screened-in options were ranked against one another (by site) utilizing a SE evaluation. To perform the SE evaluation, the pros and cons of each transfer technology were evaluated, the facility capital costs and operational cost factors were identified, and additional factors such as radioactive waste generation, collective worker doses, operational efficiency, and ease of licensing, were developed for each screened-in option and location. These factors were then utilized to evaluate weighted evaluation criteria in a SE evaluation model, which was used to evaluate and rank the screened-in options for each location. This model also allowed for a sensitivity analysis to be performed assessing the impact on the ranking of the screened-in options if the evaluation criteria were differently weighted.

## CUTTING APPROACHES

While there is considerable experience with placing UNF into DSCs of various types, there is currently no broad body of field experience for opening the DSCs to remove and re-package the UNF assemblies. With few exceptions, experience is limited to the demonstration of tooling and/or techniques required to be demonstrable during initial ISFSI startup. Furthermore, there is no identified experience opening any DSC type with efficiency in mind. Instead, industry experience has been limited to observations and operations of basic mechanical cutting tools to proof a procedure for extraordinary use in the event of a need to unload a DSC placed in storage.

Figure 1 shows an exploded view of a typical UNF DSC. The cutting activities typically involve the removal of the inner and outer top cover plates shown in this figure, but may also include siphon and vent port cover plates or could involve the cutting of the DSC just below these covers. DSCs to be opened/repackaged at existing operating facilities are recommended to be performed following existing procedures, tooling, and approved licensing demonstrations.

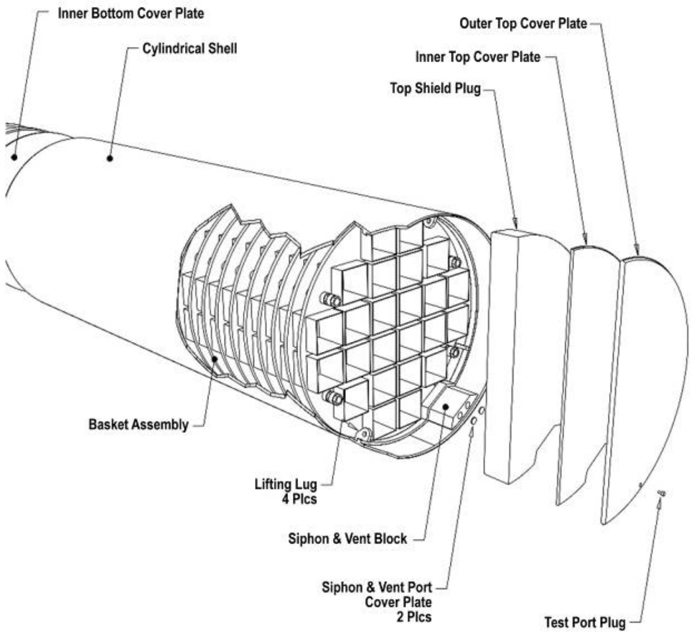



**Figure 1. Exploded View of a Typical UNF Dry Storage Canister**

## Dry Cutting Approaches

Observed technologies for cutting in the industry that do not damage the DSC include:

- ‘Skiving’ – a rotating tool that deploys a metal lathe type bit that ‘shaves’ thin ribbons from the weld joint until a separating grove is completely through the weld, Figure 2(a).
- Milling – a rotating tool that uses a spinning metal burr and traverses the weld path until a separating groove is created, Figure 2(b).
- Plasma Torch (or arc gouging) – a high speed/temperature torch changes the material state to allow a combined gas mixture to “blow” the molten material away from the weld joint, Figure 2(d).
- Slitting saw (several brands including Rotabroach) – typically used for small cuts (e.g., for port cover plates), large versions for the inner and outer cover plates do not exist, Figure 2(c).

The following alternative cutting technologies could be applied if damaging the DSC is an acceptable outcome:

- Cutting Wheel – essentially a large pipe cutter that would cut the canister wall (not the weld joint) on the outside of the shell (circumferentially) just below the shield plug, but above the UNF. This approach can be performed rapidly with the use of multiple heads on a single tool. In addition, this tool could be easily adopted to have an adjustable cutting diameter and thereby cut all sizes of canisters.

- Diamond Cable Cutting - use of an abrasive cutting cable to remove metal via cable friction and can be used to make quite precise cuts. This tool could be easily adopted to have an adjustable cutting diameter and thereby cut all sizes of canisters.
- Laser Cutting - similar to arc gouging except the heating occurs with the use of a high intensity laser and a separate delivery tool is needed to remove the molten material 'flowing' from the weld joint.
- Sawing - a metal saw that effectively uses skiving tooth-by-tooth and has been used successfully for cutting reactor vessels, internals, etc. and can be custom engineered for most metal cutting applications.

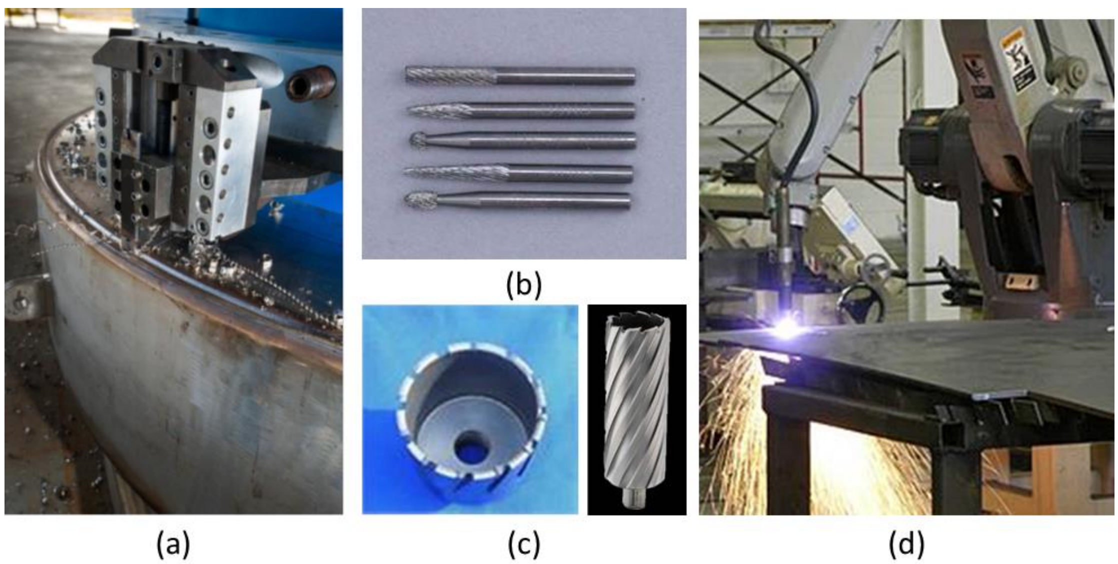



**Figure 2. Examples of Various Cutting Approaches: (a) Skiving, (b) Milling Burrs, (c) Slitting Bit, and (d) PlasmaTorch**

The total duration of the cover removal task depends not only on the technology selected for the cut, but also on the canister type (e.g., thickness of metal and weld) and preparatory time involved. In addition, currently deployed technologies attempt to re-deploy the opened canister and hence, do not destroy the DSC. However this objective may not be the same for future activities and hence, additional technologies are identified that may more efficiently cut open a DSC but potentially at the cost of damaging the DSC. Hence, selection of the appropriate cutting activity is in part dependent on the final disposition of the canister; that is, will the canister be re-used, re-purposed, recycled, or simply disposed of after having been emptied? For instance, depending on ownership of the canister and removal rate of UNF from a reactor site, a utility owned canister could be re-used for interim on-site storage or re-purposed for LLW disposal and hence, the above technologies that do not destroy the DSC would be utilized. Whereas at a CSF or a repository, a utility owned DSC would likely be recycled or disposed of or a DOE owned DSC would likely be recycled, disposed of, and/or re-purposed for LLW disposal and hence, could be damaged during the cutting operations.

However, the alternative cutting technologies cut off the top of a DSC (potentially both lids and shielding plug) so when the top of the DSC is removed, the UNF would be directly exposed to the environment above the DSC. Thus, use of these alternative cutting technologies would likely be required to be performed in a shielded hot cell (dry) or in a pool (wet) for safety purposes and require the DSC to be raised or removed from its cask, which itself is not part of the normal activity for a DSC (usually lid is cut-off and UNF lifted from the DSC in the cask). Hence, although potentially reducing cutting durations, these alternative cutting technologies will involve additional handling activities in a hot cell or pool not associated with the normal operations associated with emptying a DSC (no trunnions on DSCs). Furthermore, these alternative cutting technologies will remove the top portion of the DSC and hence, after UNF removal, consideration of the means to handle this DSC (e.g., moving and lifting) need to be planned (e.g., placement of a temporary lid over the cut DSC).

Although several different cutting alternatives and combinations have been proposed and studied at various levels, the associated times estimated for performing these cutting activities have not been fully established nor validated. However, the AREVA TN cutting technique for opening the NUHOMS® type canisters (which uses skiving to open circumferential welds and milling to separate vent/siphon block welds) has been demonstrated and frequently performed in a training setting to an extent that the estimated times and expertise are available from these exercises. Combining these times with demonstrated handling times produces reliable estimates. Hence, the dry cutting technology recommended to be applied to a DSC is the skiving process to open circumferential welds and the milling process to open the blocks over the vent/siphon ports. This technology has been demonstrated, is fairly simple to deploy, and often supports a licensing condition for retrieval of UNF from the DSCs. In addition, compared to the alternative dry approaches this technology is considered to have the least drawbacks and the highest reliability.

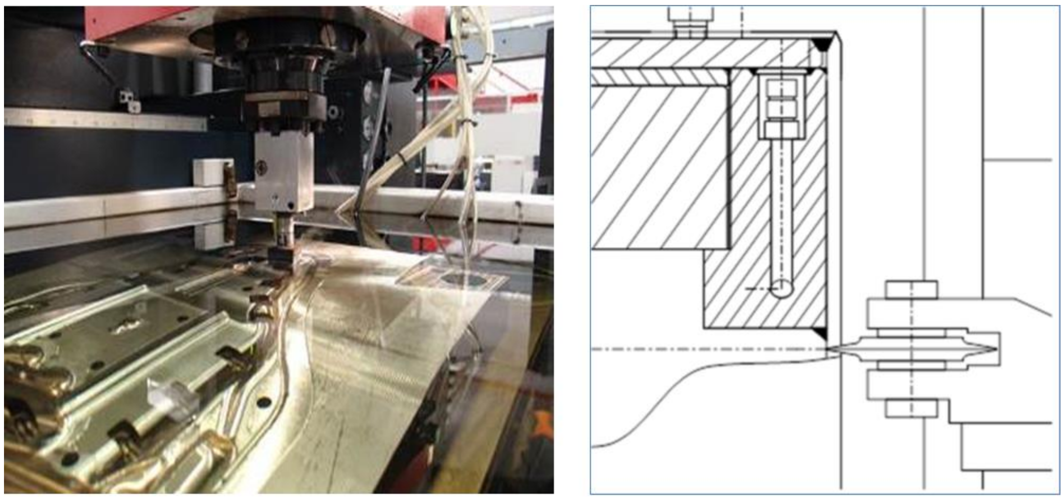
**Wet Cutting Approaches**

Each of the options discussed for dry cutting could be applied to wet cutting after some modification. However, the more promising two cutting technologies that can be applied in a wet environment include:

- Electrical Discharge Machining (EDM) – process where material (e.g., weld) is removed by a series of rapidly recurring electrical current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage, Figure 3(a).

- Cutting Wheel – essentially a large pipe cutter that would cut the canister wall (not the weld joint) on the outside of the shell (circumferentially) just below the shield plug, but above the UNF. This approach can be performed rapidly with the use of multiple heads on a single tool. In addition, this tool could be easily adopted to have an adjustable cutting diameter and thereby cut all sizes of canisters, Figure 3(b).

The principal difference between these two technologies is the EDM process will probably not damage the DSC shell, whereas the cutting wheel process cuts a portion of the shell off with the top of the DSC (potentially both lids and shielding plug). The EDM process will require multiple cuts to remove both DSC lids and covers over the ports, whereas the cutting wheel process would likely require only one cut. However, before these wet cutting activities take place, the DSC should be filled with (borated) water to minimize the release of contaminants from the DSCs into the pools and to prevent any potential thermal shock to the UNF assemblies as a result of rapid rewetting of the contents of the DSCs. Currently, this task is performed using the vent and siphon ports, which themselves need to be cut out to gain access. Making these cuts on a DSC located deep down in the pool will not be a trivial activity and it is recommended that the cuts be performed prior to entry into the pool (as done for dry cutting activities). Furthermore, the limitations associated with the dry wheel cutting activity (raising/removing DSC from its cask and handling of DSC) will also apply to the wet cutting activity. Thus, considering these issues, the wet cutting technology recommended to be applied to a DSC is the EDM process.



(a) (b)

**Figure 3. Examples of Various Cutting Approaches: (a) Electrical Discharge Machining and (b) Cutting Wheel**

## REPACKAGING TECHNOLOGIES

Based on AREVA's significant experience with unloading UNF in pools and hot cells from transportation casks at the La Hague reprocessing/recycling facility near Cherbourg, France, AREVA TN's historical activities associated with the development of dry transfer facilities for the U.S., and AREVA's experience with repackaging wastes using mobile facilities in France, the following four repackaging technologies were identified for potential application to moving UNF from DSCs to STADs:

- Spent Fuel Pool (SFP) pool transfers (wet)
- Dry Transfer System (DTS) hot cell transfers (dry)
- Mobile Hot Cell (MHC) hot cell transfers (dry)
- Fixed Hot Cell (FHC) hot cell transfers (dry)

Each of these technologies are briefly described below and then ranked against one other for application at a reactor site and a CSF/repository site by a SE evaluation that also included a hybrid approach combining the SFP and FHC at the CSF/repository.

### SFP Transfer Technology

The use of SFP at reactor sites to move and store UNF has been the standard and proven approach for the nuclear industry. Its application can also be standalone at the reactor sites, ISFSI, CSF, and repository; or can be coupled with the other systems like the hot cell or MHC for additional capabilities (the hybrid approach). The transfer of UNF to a STAD in a SFP at a reactor site, CSF, or repository will be very similar to one another. The layout within the pools between the different sites may be different, but otherwise, the handling concepts of the UNF will be the same. However, at a reactor site there is likely to be insufficient room for a DSC and a STAD to both simultaneously reside in the SFP. Hence, operations at a SFP will require UNF to be first unloaded from the DSC into storage racks in the SFP and then the STAD(s) can be loaded in the SFP. Furthermore, all the UNF from a DSC should be unloaded into the SFP regardless if all of it will fit into the STAD(s) to be loaded due to the difficulty of working with a partially filled DSC. At non-reactor sites, the SFP can be designed to accommodate both the DSC and the STAD and hence, the UNF transfer would be directly from the DSC to the STAD(s) with no need to utilize a spent fuel pool rack (the DSC would act as the rack). However a spent fuel pool rack is still recommended for the non-reactor sites to provide lag storage of UNF and thereby provide more flexibility for the loading of STADs.

Furthermore, SFPs at reactor sites are limited in their capability to unload DSCs, or load STADs for various reasons, including: constrained by pool and resource needs by the operating plant, pool storage space limitations (i.e., limited lag storage capacity while maintaining full core offload capability), ability to process or store unloaded DSCs, and inability to unload a DSC directly to a STAD. Since STADs have a smaller payload capacity (ranging from 6 to 10 MTHM compared to up to 16 MTHM for DSCs), more STADs would need to be loaded to meet reactor discharge demands, thus requiring more time, space, and resources for UNF loading.

The remaining loading activities for the STAD (placement of shield plugs and lids, draining of DSC, etc.) are essentially the same as that for a DSC at a reactor site.

**DTS Transfer Technology**

The description of the UNF transfer activity in a DTS is in large part based on the approach to unloading UNF assemblies into receiving casks proposed by TN in an Electric Power Research Institute (EPRI) report [2], cold-tested at Idaho National Lab (INL) [3] and evaluated by the NRC [4]. Some design modifications were made to improve the operation and potential throughput of the original design to that requested by DOE for this activity.

The DTS and its supporting infrastructure are comprised of as many as six distinct areas, depending on where a DTS is located: (1) a cask receiving and shipping area, as needed; (2) a preparation area for a cask loaded with a DSC; (3) a preparation area for a transfer cask to be loaded with a STAD (this area could be shared with the DSC cask preparation area); (4) a shielded lower access area and upper transfer confinement area for the unloading of UNF from the DSC and the loading of UNF into the STAD; (5) a post-unloading operation area for a cask loaded with a DSC (now empty); and (6) a post-loading operation area for a cask loaded with a STAD (now loaded with UNF assemblies). Radiological surveys and decontamination of the DSC cask and full STAD would take place in the cask preparation area, but a dedicated decontamination area would be required to improve throughput, especially if the inner basket of the empty DSCs are removed for disposal (potentially recycling the metal canister). In a single-line DTS facility of relatively low throughput, post-loading and post-unloading would be performed in the cask preparation area. Figure 4 shows a cross-section of a potential design for a single-line DTS facility.

In addition to these features, a DTS facility located at a non-reactor site will likely have more than one line to improve throughput and could be located at a nearby auxiliary pool to provide additional operability flexibility (e.g., pool could be used to deal with failed fuel). A separate decontamination facility for DSCs and their casks may also be beneficial to reduce the quantity of waste associated with used DSCs at a non-reactor site. A separate storage area for empty DSCs and their casks, if not reused, may also be provided to limit the location of potentially contaminated equipment. Figure 5 shows a plan view for a potential 'counter-flow' DTS with two lines, one for STAD and one for DTS casks. In this configuration, STADs and DSCs move in opposite directions. There are two cask preparation areas, one side dedicated to processing empty DSCs (preparing empty STADs for UNF loading and initial decontamination of unloaded DSCs) and the other side dedicated to processing full DSCs (cutting lids on DSCs and welding lids on STADs), with the actual UNF transfer between DSC and STAD taking place in the lower access area. The cask trolley tracks can be designed with switches and tracks running along the outside of the building to allow trolleys to move from the exit area back to the entry area. With a six-trolley design, it is possible to improve throughput by having up to six canisters (three DSCs and three STADs) being processed at any given time.

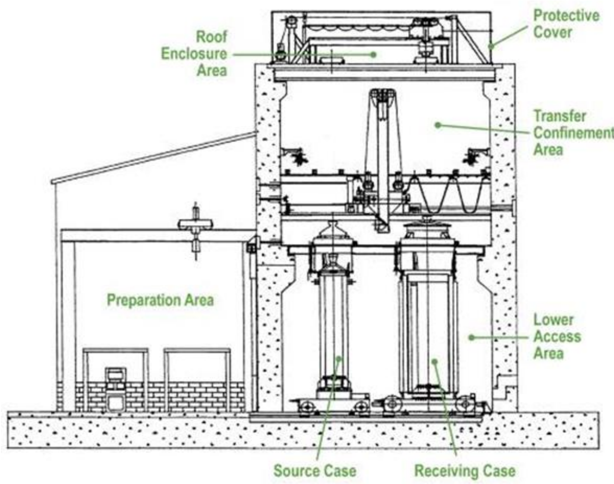



**Figure 4. Cross-section of the TN/EPRI Conceptual Design for a Dry Transfer System [2]**

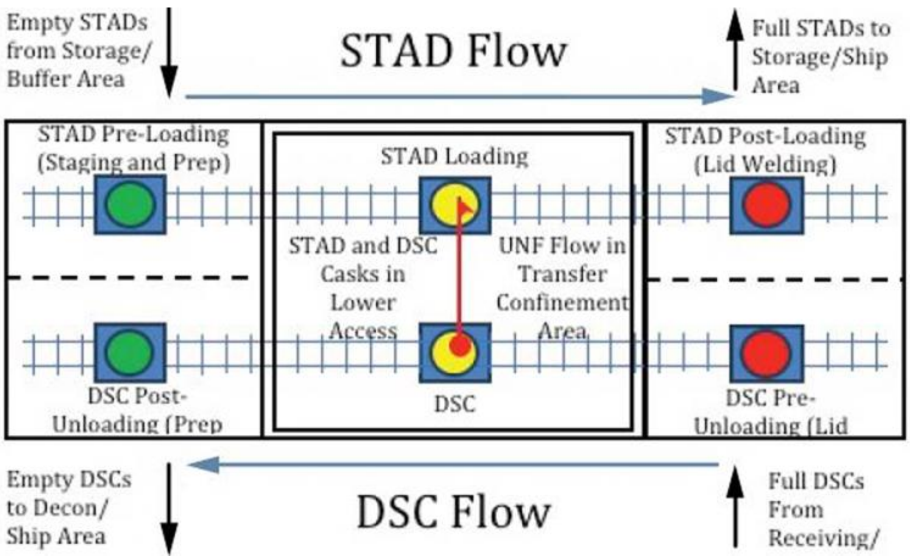



**Figure 5. Plan View of High-throughput DTS with Parallel Lines and Separate Cask Preparation Areas**

**MHC Transfer Technology**

The design of the fuel transfer activity in an MHC is based on the synthesis of the design from the following facilities: (1) the approach to unloading waste drums within the Commissariat à l'énergie atomique (CEA) complex using the Enceinte de Reprise des Futs de Bitume, (ERFB) (Bituminized Drum Retrieval Facility, Figure 6(a)), Enceinte de Reprise et Conditionnement des Futs (ERCF) (Drum Retrieval and Repackaging Enclosure, Figure 6(b)), and the FOSSes Evacuees et Assainies (FOSSEA) (Legacy Waste Recovery and Trench Cleanup) systems, Figure 6(c); (2) the approach to loading UNF assemblies within the DTS described above; and the approach to loading and unloading UNF assemblies within the FHC system described below.


**Figure 6. MHC Examples: (a) ERFB Project (1st Generation), (b) ERCF Project (2nd Generation), and (c) FOSSEA (3rd Generation)**

The MHC and its supporting infrastructure are comprised of eight distinct areas: (1) a cask receiving and shipping area; (2) a cask preparation area/loading pad for a cask loaded with a DSC; (3) a cask preparation area/loading pad for a transfer cask to be loaded with a STAD; (4) an MHC for the unloading of the DSC and the loading of the STAD; (5) a post-unloading operation/unload pad area for a cask loaded with a DSC (now empty); (6) a post-loading operation area/temporary storage area for a cask loaded with a STAD (now loaded with UNF assemblies); (7) a remote operating control room with support systems; and (8) a pit for transfer operations. Figure 7 provides a sketch of a potential layout of the facility (the MHC is on rails and moves over the casks with the DSCs and the STADs located below grade) and Figure 8 provides a plan view of a DSC moving through the facility (the DSCs and MHC move left to right in this figure). A separate decontamination facility for DSCs and their casks may also be beneficial to reduce the quantity of waste associated with used DSCs at a non-reactor site. A separate storage area for empty DSCs and their casks, if not reused, may also be needed to limit the spread of potential contamination from this equipment. Additional pits/trenches could also be added to increase the rate at which transfer activities can occur and thereby improve facility throughput.

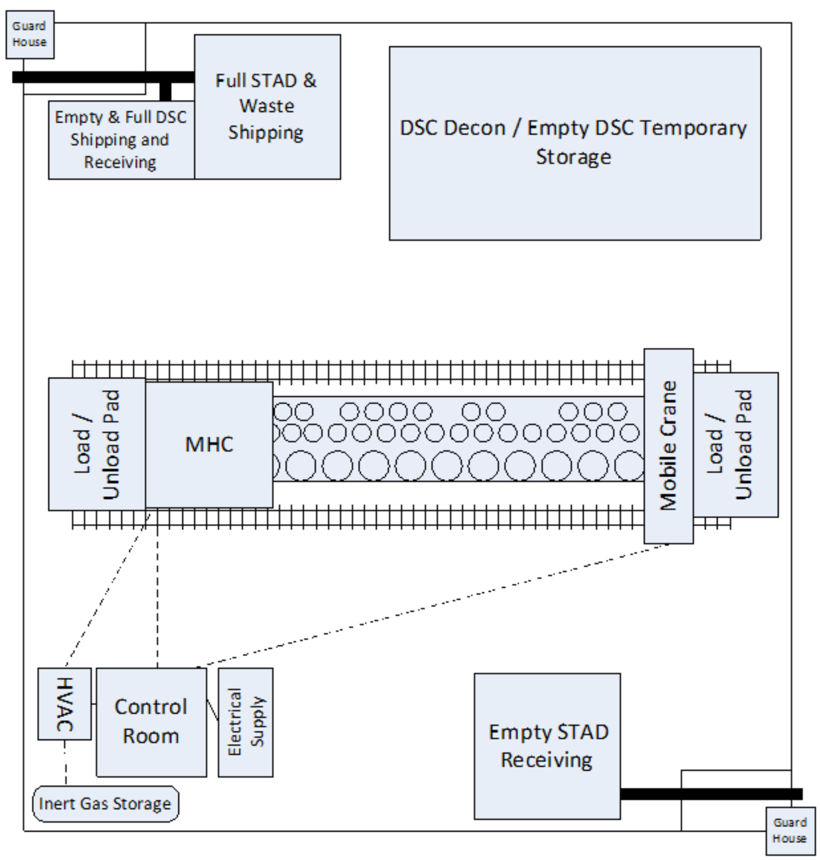



**Figure 7. MHC Footprint**

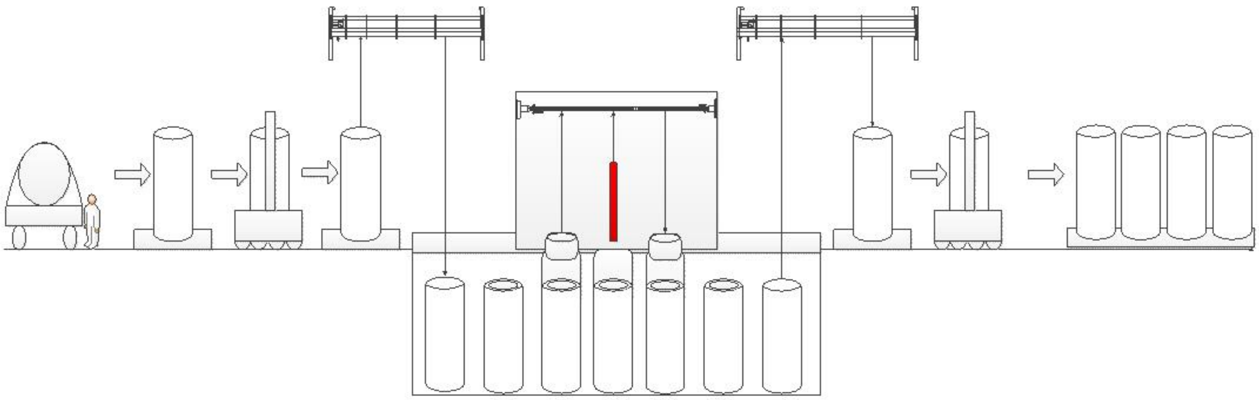


**Figure 8. DSC Movement through the MHC**

## FHC Transfer Technology

The fuel transfer activity in a fixed hot cell is primarily based on the approach to unloading UNF assemblies at La Hague's T0 facility [5] and on the approach to loading UNF assemblies within the DTS described above and at the ZWILAG dry transfer facility in Switzerland. The hot cell and its supporting infrastructure are comprised of six distinct areas: (1) a cask receiving and shipping area; (2) a cask preparation area for a cask loaded with a DSC; (3) a cask preparation area for a transfer cask to be loaded with a STAD; (4) a hot cell for the unloading of the DSC and the loading of the STAD; (5) a post-unloading operation area for a cask loaded with a DSC (now empty); and (6) a post-loading operation area for a cask loaded with a STAD (now loaded with UNF assemblies). Figure 9 provides a sketch and labeling of a potential layout of the facility. In addition to these features, a hot cell could also be connected to a nearby pool via a transfer channel to provide additional operability flexibility (e.g., pool could be used to deal with failed fuel). A separate decontamination facility for DSCs and their casks may also be beneficial to reduce the quantity of waste associated with used DSCs at a CSF or repository. A separate storage area for empty DSCs and their casks/overpacks, if not reused, may also be beneficial to have to limit the spread of potential contamination from this equipment and allow for some lag storage to a decontamination facility.

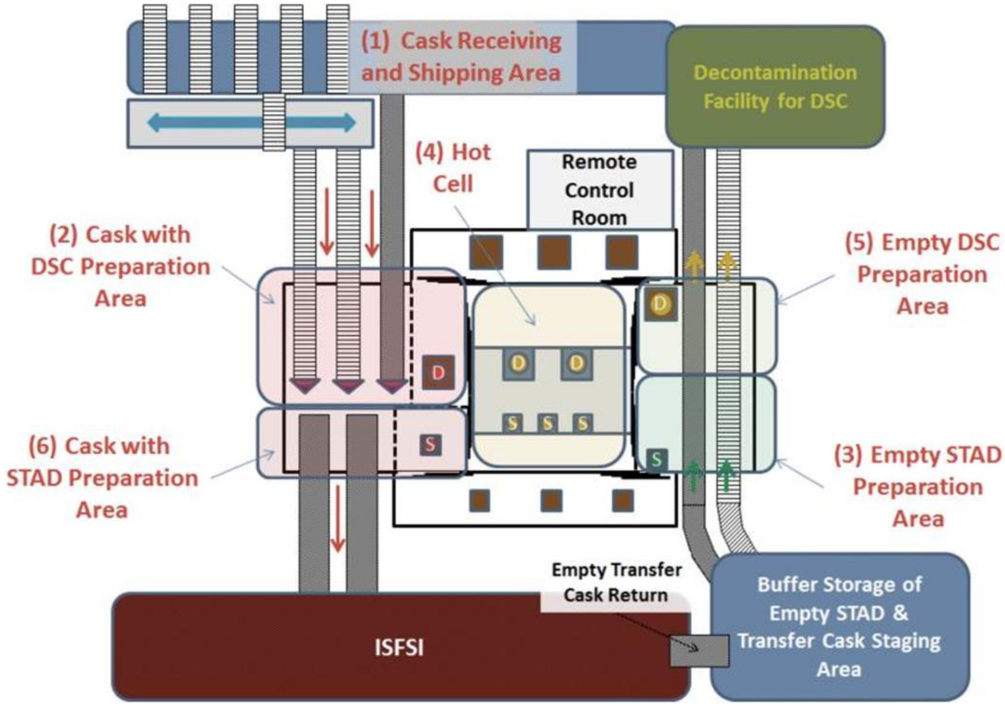



**Figure 9. Layout of a FHC**

## SE EVALUATION

A SE evaluation, conforming with DOE Order 413.3B, was performed to identify the most practical and efficient operation for the opening of a DSC and the transfer of the UNF from the DSC to a STAD at a reactor site and a CSF/repository site. This evaluation began with identifying a comprehensive set of scenarios for performing these actions at all the sites. This resulted in identifying 22 generic scenarios. When considering the different technologies available for making this transfer, 60 potential options were identified (12 for reactor sites and 24 for both the CSF and repository sites). After applying regulatory and specific performance requirements, 4 options for reactor sites and 7 options at both the CSF and repository sites remained to be evaluated by the SE evaluation. The AREVA and URS team then established 7 criteria to evaluate these options against one another, including:

- Life cycle cost – upfront costs
- Life cycle cost – operations costs
- Operational efficiency
- Technical maturity
- Ease of licensing
- Waste generation
- Dose

A pairwise comparison was then performed to weight the importance of each of the criteria. Figure 10 shows the results of the weighting for the reactor and CSF/repository sites.

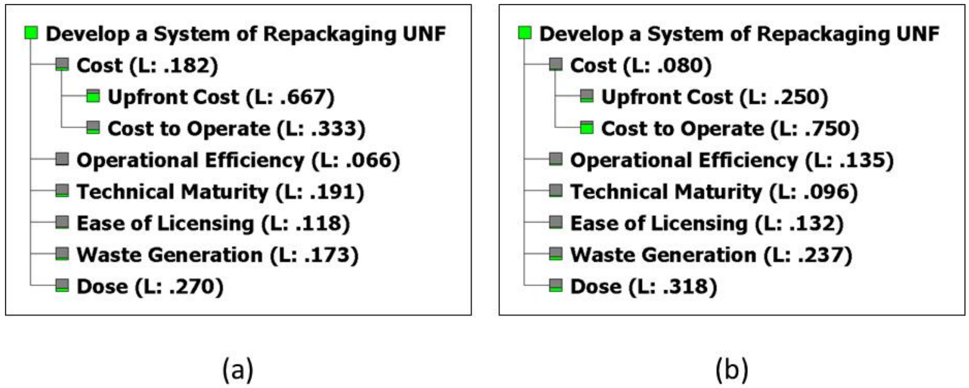



**Figure 10. Evaluation Criteria Weighting for: (a) the reactor site and (b) the CSF/repository site**

For each option (e.g., Option 1: SFP at reactor site with dry cutting and wet unloading-loading), data for each of the evaluation criteria was compiled. This data was then utilized in a pairwise comparison for the options at each of the sites and a relative ranking established. Figures 11 and 12 show the results of the SE evaluation for the options evaluated at the reactor and CSF/repository sites, respectively. For the reactor site, Option 1 which includes dry cutting and wet unloading-loading at the SFP is clearly the highest ranked option. For the CSF/repository, Option 5a which is essentially the same as Option 1 is the highest ranked option. Thus, the dry cutting and wet unloading-loading option at a SFP is currently recommended at all sites.

However, the Team further recommended the DTS or Fixed Hot Cell option (as both rated similarly, <1 percent difference in preference) for further evaluation for CSF/repository deployment with the SFP option, as they have the potential to perform better than the pool option in certain areas (e.g., dose). At this time, neither option has the established operating history, technical maturity, or anticipated ease of licensing as the SFP option, but have the ability to provide the CSF/repository greater operating flexibility (i.e., having both wet and dry transfer options available at a CSF/repository reduces the risk of not meeting throughput needs due to a common mode failure applying to all the wet or all the dry transfer facilities).

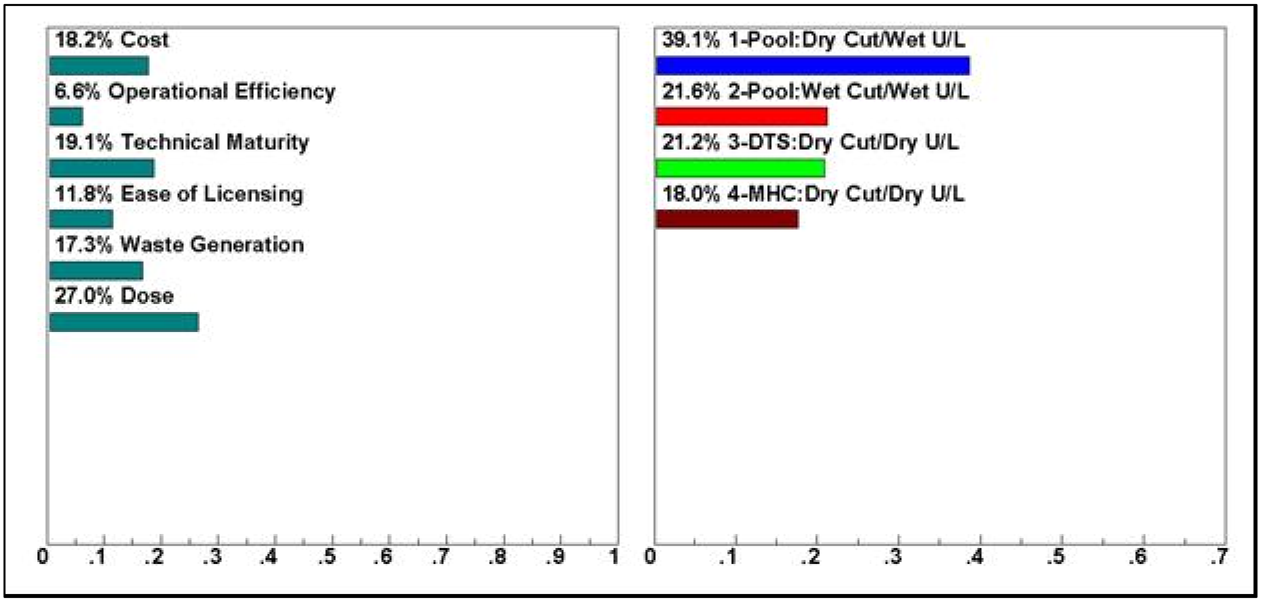



**Figure 11. Reactor Site Weighted Evaluation Results**

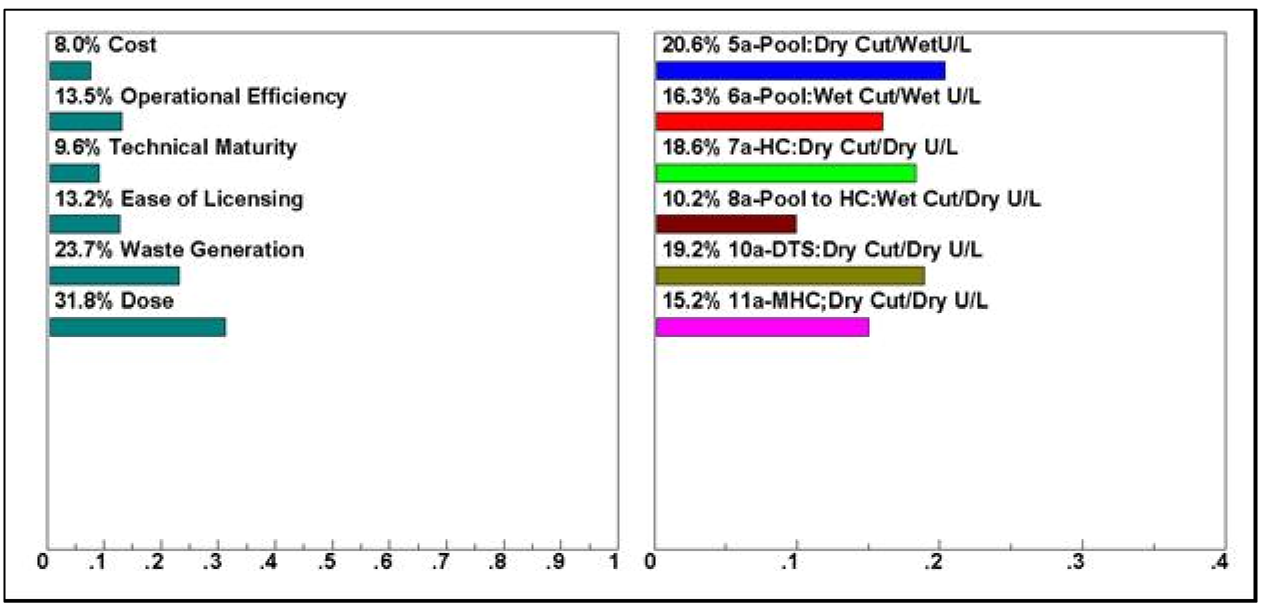



**Figure 12. CSF/Repository Site Weighted Evaluation Results**

## CONCLUSION

A systematic approach for ranking the viable repackaging options of UNF from a DSC to a STAD at a reactor and CSF/repository location was performed, with particular emphasis on selecting the preferred canister cutting technology and selecting repackaging technologies with low life cycle costs and reduced waste generation. Some repackaging methods favor one criterion over another, and a SE evaluation was performed to effectively evaluate these trade-offs. For the reactor and the CSF/repository sites, the highest ranked option involved using the skiving dry cutting approach with the SFP technology to perform the repackaging of the UNF. However for the CSF/repository, three results ranked relatively closely and based on experience at AREVA's La Hague facility, which indicates a higher throughput can be processed by a fixed hot cell, the team recommended a hybrid option that utilizes both dry and wet UNF loading and unloading. This combination of repackaging activities is recommended for several reasons including:

- To minimize potential issues created by rewetting UNF that has been maintained dry for several decades (e.g., thermal shock, hydrides) [Advantage for Dry Repackaging]
- To minimize contamination and wastes produced from the handling of failed UNF [Advantage for Wet Repackaging]
- To minimize wastes produced from the handling of normal UNF [Advantage for Dry Repackaging]
- To meet throughput requirements [Advantage for Dry Repackaging]
- To provide a demonstrated approach for loading UNF [Advantage for Wet Repackaging]

Finally, the team also considered if any of the options identified in this paper could be recommended for the repackaging of UNF located at stranded sites. None of the options developed and evaluated in this report could be recommended by the team. Instead, the team recommends shipping the UNF from the stranded sites to a CSF/repository where the UNF can be repackaged. If repackaging at a stranded site were necessary, the team suggests developing a resized MHC with a reduced throughput for repackaging the UNF. The larger throughput associated with the MHC described in this paper would not be necessary at these sites and could facilitate the mobility of this MHC design between these sites.

## REFERENCES

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