Task Order 12 – Standardized Transportation, Aging, and Disposal Canister Feasibility Study

Appendix A
ProFormas

RPT-3008859-000

Prepared by: AREVA Federal Services LLC

REVISION LOG

Rev.	Date	Affected Pages	Revision Description

A.0 PRO FORMA Descriptions

This Appendix presents pro forma descriptions of STAD options identified by the AREVA Team. These options were potential candidates for meeting the functions and requirements of a STAD as defined in Appendix D. The pro formas were generated in the early stages of the SE process and were used as a basis for establishing the feasibility of STAD options during the screening process and later during the evaluation process leading to the Team recommendations. The pro formas were prepared by owners (champions) assigned within the AREVA Team.

NOTE: Option 1 did not pass the screening stage due to the corrosion issues of using a carbon steel well pipe to house UNF, it was therefore not considered feasible. As Option 3 is essentially the same as Option 1 with a thinner stainless steel wall, Option 3 represented a feasible application of this configuration. Option 1 is included here for completeness.

A.1 STAD OPTION 1

A.1.1 Option 1 Description

This option provides a STAD for use in all repository types. It is selected to be compatible with: a deep borehole; backfilled shale, clay or crystalline; un-backfilled clay, shale, volcanic, or crystalline; and salt. It is considered a small STAD.

This STAD has the lowest capacity. Fabrication material is standard carbon steel well pipe, which should minimize materials costs as opposed to using stainless steel. The STAD canister wall thickness for carbon steel would be 0.4 inches as opposed to 0.25 inches for stainless steel construction.

Table A-1 shows the concept parameters for the 1 PWR/1 BWR STAD canister.

Table A-1. Option 1 Concept Parameters

Parameter	Value
UFA Capacity, PWR/BWR	1/1
Canister OD, in	13.4
Canister ID, in	12.6
Canister wall thickness, in	0.4
Canister length*, in	198
Cell size, PWR/BWR (in x in)	8.9x8.9/6x6
Cell length, in	181.5

*May be increased to include a handling feature.

Figure A-1 shows the conceptual arrangement of a single PWR fuel assemblies in a 13.4- in OD STAD canister. Figure A-2 shows the conceptual arrangement of a single BWR FA in a 13.4-in OD STAD.

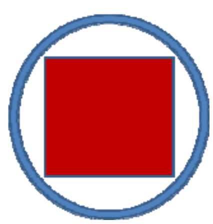

Figure A-1. Option 1, 1 PWR FA STAD Configuration

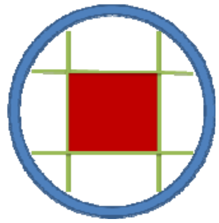

Figure A-2. Option 1, 1 BWR FA STAD Configuration

A.1.2 Option 1 Storage and Transportation Configuration

This concept allows at least 12 STADs to be bundled in a handling frame, then handled, stored, and transported as a larger unit to minimize storage and transportation costs. The handling frame is an unsealed cylinder with drain holes in the bottom, a bolted lid, and means for lifting. STADs would be loaded into the handling frame while it is in the UNF pool, or using a transfer shield, by dry transfer. Internal aluminum plates may be needed between the canisters to transfer decay heat to the surface, thus maintaining peak cladding temperatures below the normal condition storage temperature limit. Also, poison plates may be required during the transportation mode to meet sub-criticality criteria under the assumptions of fresh fuel and optimum moderation. The handling frame, with STADs included, would be placed in the appropriate overpack for storage and transport. Existing site weight and handling limits and all transportation weight and size limits would not be exceeded. Figure A-3 shows the conceptual arrangement of twelve 13.4 inch OD STADs in a handling frame.

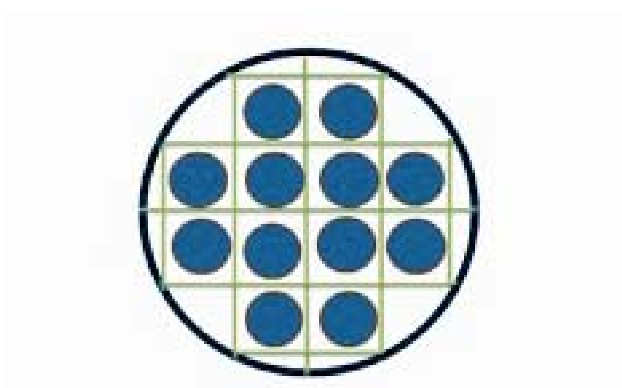

Figure A-3. Option 1, 12 STAD Handling Frame Configuration

A.2 STAD OPTION 2

A.2.1 Option 2 Description

This Option provides a STAD for use in all repository types. It is selected to be compatible with: a deep borehole; backfilled shale, clay or crystalline; un-backfilled clay, shale, volcanic, or crystalline; and salt. It is considered a small STAD.

This Option uses rod consolidation techniques. Fuel rod consolidation is the process of removing rods from fuel assemblies and placing them into a consolidated fuel rod canister, in this case a STAD, with the intent of achieving a fuel compaction ratio on the order of two to one [2] (i.e., the fuel rods from two fuel assemblies taking up no more volume than one fuel assembly). The discarded fuel assembly skeleton structure could be disposed of as GTCC waste at a ratio of about one skeleton can for every ten UNF fuel rod cans.

This Option uses a circular cross section STAD that will fit into the same size borehole as Option 1. This is slightly larger than the envelope of a PWR fuel assembly and contains the rod equivalent of up to 2 PWR or 4 BWR FAs. Stainless steel is selected for the canister material due to its compatibility with fuel pools and corrosion resistance.

Table A-2 shows the concept parameters for the small consolidated rod STAD.

Table A-2. Option 2 Concept Parameters

Parameter	Value
Canister OD, in	13.4
Canister ID, in	12.60
Canister wall thickness, in	0.39
Canister material	stainless steel
Borehole spacing, ft	656
Limit on spacing	thermal interaction
Number of boreholes	950
Disposal canister containment function	none after emplacement

Figure A-4 shows the conceptual arrangement of consolidated rods in a 13.4-in OD STAD.

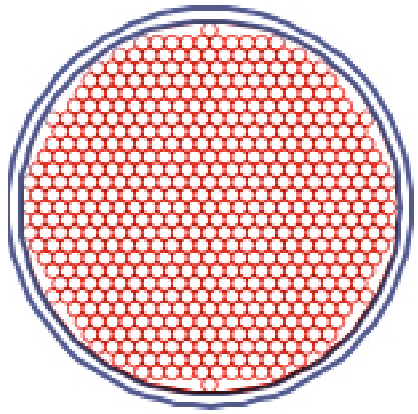

Figure A-4. Option 2, STAD with Consolidated PWR Fuel

A.2.2 Option 2 Storage and Transportation Configuration

This concept allows at least 12 STADs to be bundled in a handling frame then handled, stored, and transported as a larger unit to minimize storage and transportation costs. The handling frame is an unsealed cylinder with drain holes in the bottom, a bolted lid, and means for lifting. STADs would be loaded into the handling frame while it is in the fuel pool, or using a transfer shield, by dry transfer. Internal aluminum plates may be needed between the canisters to transfer decay heat to the surface, thus maintaining peak cladding temperatures below the normal condition storage temperature limit. Also, poison plates may be required during the transportation mode to meet sub-criticality criteria under the assumptions of fresh fuel and optimum moderation. The handling frame, with STADs included, would be placed in the appropriate overpack for storage and transport. Existing site weight and handling limits and all transportation weight and size limits would not be exceeded.

Figure A-5 shows the conceptual arrangement of twelve 13.4-in OD STADs in a handling frame.

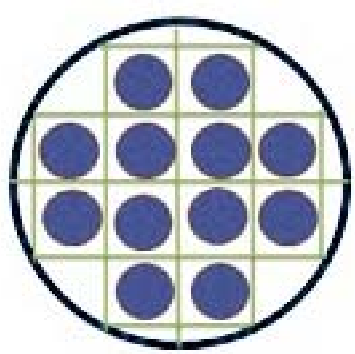

Figure A-5.Option 2, 12 STAD Handling Frame Configuration

A.3 STAD OPTION 3

A.3.1 Option 3 Description

This Option provides a STAD for use in all repository types. It is selected to be compatible with: a deep borehole; backfilled shale, clay or crystalline; un-backfilled shale, crystalline, or volcanic; and salt. It is considered a small STAD.

This STAD has a low capacity. This canister design option is the same as Option 1 except that it has a 0.25-in wall thickness, rather than a 0.4-in wall thickness and stainless steel is selected for the canister material due to its compatibility with fuel pools and corrosion resistance.

Table A-3 shows the concept parameters for the 1 PWR/1 BWR STAD canister.

Table A-3. Option 3 Concept Parameters

Parameter	Value
UFA Capacity, PWR/BWR	1/1
Canister OD, in	13.1`
Canister ID, in	12.6
Canister wall thickness, in	0.25
Canister length*, in	198
Cell size, PWR/BWR (in x in)	8.9x8.9/6x6
Cell length, in	181.5
Canister Material	Stainless steel

*May be increased to include a handling feature.

Figure A-6 shows the conceptual arrangement of a single PWR FA in a 13.1-in OD STAD canister. Figure A-7 shows the conceptual arrangement of a single BWR FA in a 13.1-in OD STAD.

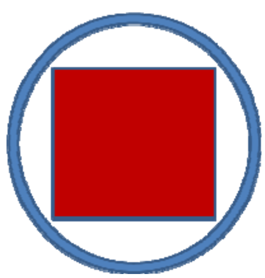

Figure A-6. Option 3, 1 PWR FA STAD Configuration

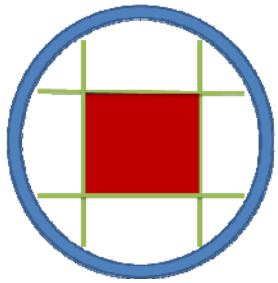

Figure A-7. Option 3, 1 BWR FA STAD Configuration

A.3.2 Option 3 Storage and Transportation Configuration

This concept allows at least 12 STADs to be bundled in a handling frame, then handled, stored, and transported as a larger unit to minimize storage and transportation costs. The handling frame is an unsealed cylinder with drain holes in the bottom, a bolted lid, and means for lifting. STADs would be loaded into the handling frame while it is in the UNF pool, or using a transfer shield, by dry transfer. Internal aluminum plates may be needed between the canisters to transfer decay heat to the surface, thus maintaining peak cladding temperatures below the normal condition storage temperature limit. Also, poison plates may be required during the transportation mode to meet sub-criticality criteria under the assumptions of fresh fuel and optimum moderation. The handling frame, with STADs included, would be placed in the appropriate overpack for storage and transport. Existing site weight and handling limits and all transportation weight and size limits would not be exceeded.

Figure A-8 shows the conceptual arrangement of twelve 13.1-in OD STADs in a handling frame.

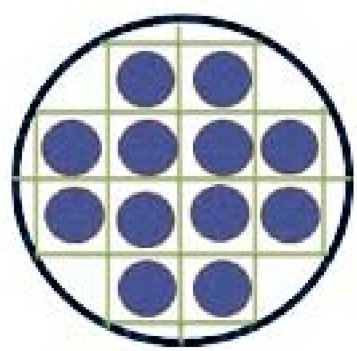

Figure A-8. Option 3, 12 STAD Handling Frame Configuration

A.4 STAD OPTION 3a

A.4.1 Option 3a Description

This Option provides a STAD for use in all repository types. It is selected to be compatible with: a deep borehole; backfilled shale, clay or crystalline; un-backfilled clay, shale, volcanic, or crystalline; and salt. It is considered a small STAD.

This canister is the same as the Option 3 canister except that it is large enough in diameter to accommodate 2 BWR FAs. It will require a slightly bigger borehole than Options 1, 2 and 3. Stainless steel is selected for the canister material due to its compatibility with fuel pools and corrosion resistance.

Table A-4 shows the concept parameters for the 1 PWR/2 BWR STAD canister.

Table A-4. Option 3a Concept Parameters

Parameter	Value
UFA Capacity, PWR/BWR	1/2
Canister OD, in	15.0
Canister ID, in	14.5
Canister wall thickness, in	0.25
Canister length*, in	198
Cell size, PWR/BWR (in x in)	8.9x8.9/6x6
Cell length, in	181.5
Canister Material	Stainless steel

*May be increased to include a handling feature.

Figure A-9 shows the conceptual arrangement of a single PWR FA in a 15.0-in OD STAD. Figure A-10 shows the conceptual arrangement of 2 BWR FAs in a 15.0-in OD STAD.

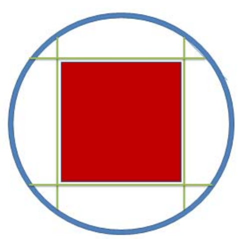

Figure A-9. Option 3A, 1 PWR FA STAD Configuration

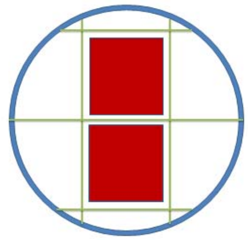

Figure A-10. Option 3A, 2 BWR FA STAD Configuration

A.4.2 Option 3a Storage and Transportation Configuration

This concept allows 12 STADs to be bundled in a handling frame, then handled, stored, and transported as a larger unit to minimize storage and transportation costs. The handling frame is an unsealed cylinder with drain holes in the bottom, a bolted lid, and means for lifting. STADs would be loaded into the handling frame while it is in the fuel pool, or using a transfer shield, by dry transfer. Internal aluminum plates may be needed between the canisters to transfer decay heat to the surface, thus maintaining peak cladding temperatures below the normal condition storage temperature limit. Also, poison plates may be required during the transportation mode to meet sub-criticality criteria under the assumptions of fresh fuel and optimum moderation. The handling frame, with STADs included, would be placed in the appropriate overpack for storage and transport. Existing site weight and handling limits and all transportation weight and size limits would not be exceeded.

Figure A-11 shows the conceptual arrangement of twelve 15.0 inch OD STADs in a handling frame.

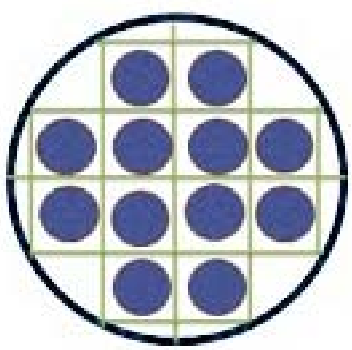

Figure A-11. Option 3a, 12 STAD Handling Frame Configuration

A.5 STAD OPTION 4

A.5.1 Option 4 Description

This Option provides a STAD for use in all repository types. It is selected to be compatible with: a deep borehole; backfilled shale, clay or crystalline; un-backfilled clay, shale, volcanic, or crystalline; and salt. It is considered a small STAD.

This Option uses rod consolidation techniques. Fuel rod consolidation is the process of removing rods from fuel assemblies and placing them into a consolidated fuel rod canister, in this case a STAD, with the intent of achieving a fuel compaction ratio on the order of two to one [2] (i.e., the fuel rods from two fuel assemblies taking up no more volume than one fuel assembly). The discarded fuel assembly skeleton structure could be disposed of as GTCC waste at a ratio of about one skeleton can for every ten UNF fuel rod cans.

This option uses a square STAD that will fit into a space slightly larger than the envelope of a PWR fuel assembly and contain the consolidated fuel from up to two PWR assemblies.

Table A-5 shows the concept parameters for the square STAD with consolidated rods.

Table A-5. Option 4 Concept Parameters

Parameter	Value
Canister width, in	8.4
Volume compaction	factor of 2

Figure A-12 shows the conceptual arrangement of fuel rods consolidated in an 8.4-in square STAD.

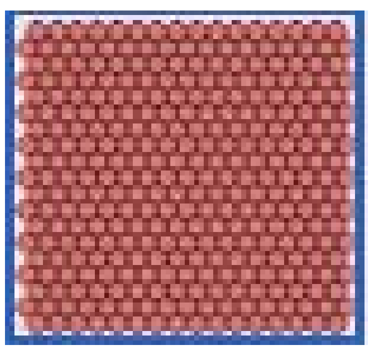

Figure A-12. Option 4 STAD with Consolidated PWR Fuel

A.5.2 Option 4 Storage and Transportation Configuration

This concept allows 21 square STADs to be bundled in a handling frame then handled, stored, and transported as a larger unit to minimize storage and transportation costs. The handling frame is an unsealed cylinder with drain holes in the bottom, a bolted lid, and means for lifting. STADs would be loaded into the handling frame while it is in the UNF pool, or using a transfer shield, by dry transfer. Internal aluminum plates may be needed between the canisters to transfer decay heat to the surface, thus maintaining peak cladding temperatures below the normal condition storage temperature limit. Also, poison plates may be required during the transportation mode to meet sub-criticality criteria under the assumptions of fresh fuel and optimum moderation. The handling frame, with STADs included, would be placed in the appropriate overpack for storage and transport. Existing site weight and handling limits and all transportation weight and size limits would not be exceeded.

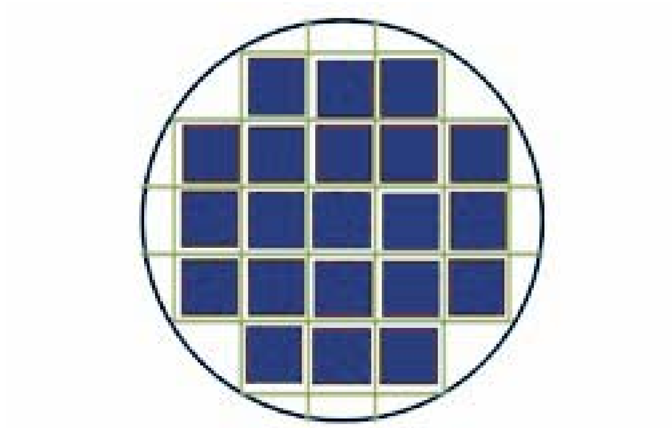

Figure A-13. Option 4, 21 STAD Handling Frame Configuration

A.6 STAD OPTION 5

A.6.1 Option 5 Description

This Option provides a STAD for use in all repository types except borehole. It is selected to be compatible with: backfilled shale, clay or crystalline; un-backfilled clay, shale, volcanic, or crystalline; and salt. It is considered a medium-size STAD.

Stainless steel material is selected for its compatibility with fuel pools and its corrosion resistance.

Table A-6 shows the concept parameters for the 4 PWR/BWR 9 canister.

Table A-6. Option 5 Concept Parameters

Parameter	Value
UFA Capacity, PWR/BWR	4/9
Canister OD, in	31
Canister ID, in	30
Canister wall thickness, in	0.5
Canister length*, in	198
Cell size, PWR/BWR (in x in)	8.9x8.9/6x6
Cell length, in	181.5
Canister material	Stainless steel

*May be increased to include a handling feature.

Figure A-14 shows the conceptual arrangement of 4 PWR FAs in a 31.0-in OD STAD canister. Figure A-15 shows the conceptual arrangement of 9 BWR FAs in a 31.0-in STAD.

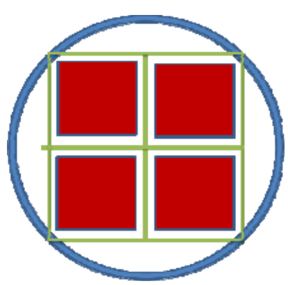

Figure A-14. Option 5, 4 PWR FA STAD Configuration

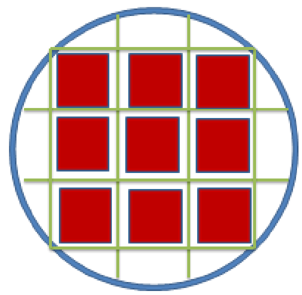

Figure A-15. Option 5, 9 BWR FA STAD Configuration

A.6.2 Option 5 Storage and Transportation Configuration

This concept allows three STADs to be bundled in a handling frame then handled, stored, and transported as a larger unit to minimize storage and transportation costs. The inner diameter of the storage frame would be approximately 68 inches. Existing site weight and handling limits and all transportation weight and size limits would not be exceeded. The handling frame is an unsealed cylinder with drain holes in the bottom, a bolted lid, and means for lifting it. STADs would be loaded into the handling frame while it is in the UNF pool, or using a transfer shield, by dry transfer. Internal aluminum plates may be needed between the canisters to transfer decay heat to the surface, thus maintaining peak cladding temperatures below the normal condition storage temperature limit. Also, poison plates may be required during the transportation mode to meet sub-criticality criteria under the assumptions of fresh fuel and optimum moderation. The handling frame, with STADs included, would be placed in the appropriate overpack for storage and transport. Existing site weight and handling limits and all transportation weight and size limits would not be exceeded.

Figure A-16 shows the arrangement of three 31.0 inch OD STADs in a handling frame for storage and transportation.

Figure A-16. Option 5, 3 STAD Handling Frame Configuration

A.7 STAD OPTION 6

A.7.1 Option 6 Description

This Option provides a STAD for use in salt and un-backfilled crystalline or volcanic repositories. It is considered a large-size STAD.

Stainless steel material is selected for its compatibility with fuel pools and its corrosion resistance.

Table A-7 shows the conceptual parameters for the 12 PWR/24BWR STAD canister.

Table A-7. Option 6 Concept Parameters

Parameter	Value
UFA Capacity, PWR/BWR	12/24
Canister OD, in	43.25
Canister ID, in	42
Canister wall thickness, in	0.62
Canister length*, in	198
Cell size, PWR/BWR (in x in)	8.9x8.9/6x6
Cell length, in	181.5
Canister material	Stainless steel

*May be increased to include a handling feature.

Figure A-17 shows the conceptual arrangement of 12 PWR FAs in a 43.25-in OD STAD canister. Figure A-18 shows the conceptual arrangement of 24 BWR FAs in a 43.25-in STAD canister.

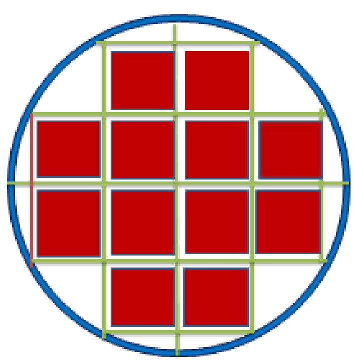

Figure A-17. Option 6, 12 PWR FA STAD Configuration

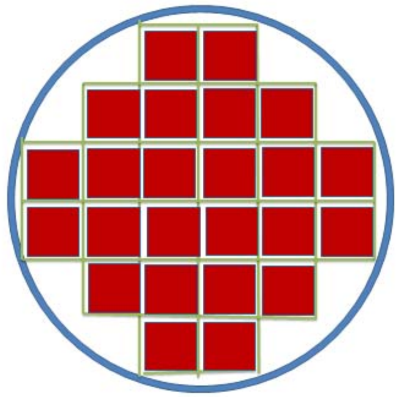

Figure A-18. Option 6, 24 BWR FA STAD Configuration

A.7.2 Storage and Transportation Configuration

With this Option, only one STAD would be handled at a time and no handling frame would be used because a STAD overpack with an internal diameter large enough to contain more than one STAD canister and provide sufficient shielding would exceed crane limits at existing reactors. Also, transportation weight and size limits would be exceeded.

A.8 STAD OPTION 7

A.8.1 Option 7 Description

This Option provides a STAD for use in un-backfilled crystalline or volcanic repositories. It is considered a large-size STAD.

This STAD is based on AFS's previous work in developing the AREVA TAD design. Stainless steel is selected for the canister material due to its compatibility with fuel pools and corrosion resistance.

Table A-8 shows the concept parameters for the 21 PWR/44 BWR STAD canister.

Table A-8. Option 7, Concept Parameters

Parameter	Value
UFA Capacity, PWR/BWR	21/44
Canister OD, in	66.25
Canister ID, in	64.75
Canister wall thickness, in	0.75
Canister length*, in	198
Cell size, PWR/BWR (in x in)	8.9x8.9/6x6
Cell length, in	181.5
Canister material	Stainless steel

*May be increased to include a handling feature.

Figure A-19 shows the conceptual arrangement of 21 PWR FAs in a 66.25-in OD STAD canister. Figure A-20 shows the conceptual arrangement of 44 BWR FAs in a 66.25-in STAD.

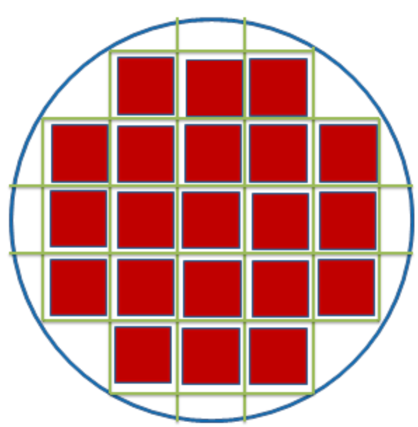

Figure A-19. Option 7, 21 PWR FA STAD Configuration

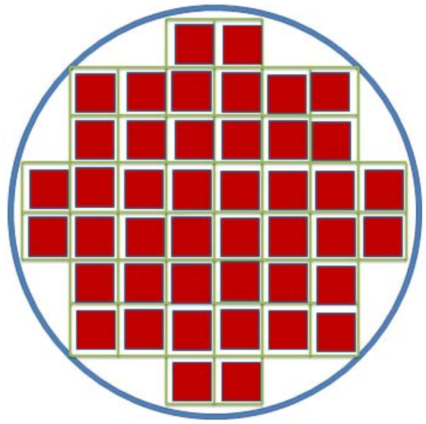

Figure A-20. Option 7, 44 BWR FA STAD Configuration

A.8.2 Option 7 Storage and Transportation Configuration

With this Option, only one STAD would be handled at a time and no handling frame would be used because a STAD overpack with an internal diameter large enough to contain more than one STAD canister and provide sufficient shielding would exceed crane limits at existing reactors. Also, transportation weight and size limits would also be exceeded.

Based on the established DOE limits for rail transport[1], a practical limit on the loaded weight of the transport cask without impact limiters is about 125 tons. This weight limit derives from the maximum impact limiter diameter dimension of 126 inches, which is a U.S. rail infrastructure dimensional limit, and 10 CFR Part 71 impact requirements for nuclear materials transportation.

A.9 STAD OPTION 8

A.9.1 Option 8 Description

This Option provides a STAD for use in un-backfilled crystalline or volcanic repositories. It is considered a large-size STAD.

This Option uses rod consolidation techniques. Fuel rod consolidation is the process of removing rods from fuel assemblies and placing them into a consolidated fuel rod canister with the intent of achieving a fuel compaction ratio on the order of two to one (i.e., the fuel rods from two fuel assemblies taking up no more volume than one fuel assembly). The rod canister has a square cross section and is 8.4 inches on each side. The rod canister is open, not sealed. The discarded fuel assembly skeleton structure could be disposed of as GTCC waste at a ratio of about one skeleton can for every 10 UNF fuel rod cans.

With this Option, the individual rod canisters are packaged into a STAD holding 21 rod canisters resulting in a TAD-sized STAD similar to Option 7; however, the MTU capacity is essentially doubled using this approach. Therefore, the Option 8 STAD holds the equivalent of 42 PWR or 88 BWR fuel assemblies in a single STAD. While igneous rock (granite, tuff, basalt) can hold a 21 PWR STAD, only the open crystalline repository can accommodate up to an equivalent of 42 PWR assemblies of fuel.

Table A-9 shows the conceptual parameters for the 21 rod canister STAD with consolidated fuel.

Table A-9. Option 8 Concept Parameters

Parameter	Value
STAD OD, ft	5.25
Canister width, in	8.4
Volume compaction	factor of 2

Figure A-21 shows the conceptual arrangement of individual fuel rods in a rod canister.

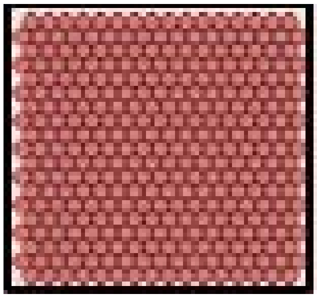

Figure A-21. Option 8, Rod Canister with Consolidated Fuel Rods

A.9.2 Option 8 Storage and Transportation Configuration

With this Option, only one STAD would be handled at a time and no handling frame would be used because a STAD overpack with an internal diameter large enough to contain more than one STAD canister and provide sufficient shielding would exceed crane limits at existing reactors. Also, transportation weight and size limits would also be exceeded.

Figure A-22 shows the conceptual arrangement of 21 rod consolidation canisters in a 63-in OD STAD.

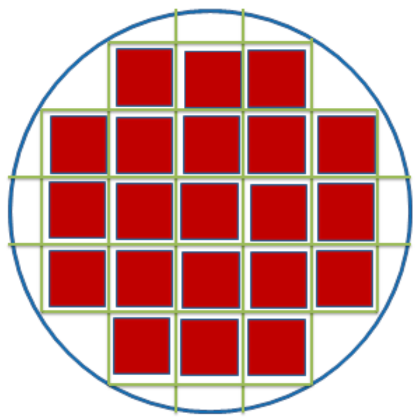

Figure A-22. Option 8 STAD with 21 Rod Consolidation Canisters