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PRELIMINARY EFFORTS RELATED TO 8-AXLE RAIL CAR DESIGN FOR TRANSPORTING SPENT NUCLEAR FUEL

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ABSTRACT

The Association of American Railroads (AAR) has published a technical standard developed specifically for railcars used during transport of spent nuclear fuel (SNF) and high-level waste (HLW): Performance Specification for Trains Used to Carry High-Level Radioactive Material, Standard S-2043. Railcars that meet S-2043 will need to be capable of transporting NRC-certified transportation casks that weigh between 164,000 lb. and 421,000 lb. over the railroad infrastructure in the United States.

A previous contract was issued by DOE to develop a cask-carrying railcar to be used to transport SNF and HLW. This effort resulted in the development of a 12-axle cask-carrying railcar design. Due to the capital costs to produce and maintain these cars, an effort has been undertaken that seeks to determine whether it is technically possible to develop an 8-axle cask-carrying railcar that meets S-2043. This paper presents the progress made under a Department of Energy (DOE) contract to prepare for future large-scale rail transport of SNF and HLW utilizing an 8-axle cask-carrying railcar that meets AAR Standard S-2043 for rail transport of SNF and HLW. This effort involves the development of a design for an 8-axle railcar and will be executed in three phases: 1) a conceptual design that will meet S-2043, 2) the performance of modeling and optimization to advance the conceptual design to a preliminary design that is ready for submittal to the AAR, and 3) the completion of a preliminary design review by the AAR Equipment Engineering Committee (EEC) that ultimately results in notification from the EEC that the railcar design is ready for prototype fabrication and testing

1. INTRODUCTION

The Department of Energy (DOE) is laying the groundwork for implementing an integrated nuclear waste management disposition system. This includes preparing for future large-scale rail transport of spent (or used) nuclear fuel (SNF) and high-level radioactive waste (HLW), since transport will be a necessary component of any integrated nuclear waste management disposition system. To achieve that objective, DOE will continue to plan for and develop options for decision-makers on the design of an integrated nuclear waste management disposition system.

The Association of American Railroads (AAR) has published a technical standard developed specifically for railcars used during transport of SNF and HLW: Performance Specification for Trains Used to Carry High-Level Radioactive Material, Standard S-2043 (Last revised 2017) [1].

SNF and HLW will be shipped in transport casks certified in accordance with 10 CFR Part 71 [2], issued by the Nuclear Regulatory Commission (NRC). The NRC has given a Certificate of Compliance (CoC) to transport cask designs supplied by various manufacturers. These transportation casks will weigh up to approximately 180 tons when loaded and contain the shipping cask, cradle and impact limiters. None of the existing railcars hauling ordinary freight across the U.S. today have been approved by AAR as Standard S-2043 compliant. Therefore, new railcars that meet S-2043 will need to be designed, approved, and fabricated to transport SNF and HLW over the railroad infrastructure in the United States. Each cask car will be required to carry only one transport cask at a time.

This paper describes the effort to prepare a conceptual design, model and optimize the conceptual design for compliant cask railcars that will meet S-2043 for rail transport of SNF and HLW, and to finalize the design.

The work scope will be performed in three phases: (1) Completion of an initial conceptual design of a cask railcar meeting the requirements described in the contract's Statement of Work; (2) modeling and optimization of the conceptual design, and (3) finalize the design. Manufacture of a prototype railcar, any prototype railcar testing, obtaining AAR conditional approval and manufacture of production railcars will occur under separate contract(s).

A related effort is currently underway (prototype testing) to develop a similar cask railcar to be used to transport SNF and HLW. The effort resulted in a cask railcar design that has 12 axles.

Due to the increased capital costs to produce and maintain 12-axle railcars, this effort seeks to determine whether it is technically possible to develop a cask railcar that would utilize 8 axles. The U.S. rail system has functional 8-axle cars with payload capacities described in this paper, but they were not designed to, nor have they passed, S-2043 rules. The insights from the 12-axle design and testing effort will be utilized to the extent practical for the 8-axle railcar design effort. Additionally, the cask railcars must also comply with other applicable standards as specified in the Oak Ridge National Laboratory (ORNL) report [3].

SNF and HLW will be transported in dedicated trains, which will be comprised of the locomotive(s), buffer cars (2), cask car(s), and an escort car. The 8-axle railcar design task is only developing a design for the cask car. Locomotives are assumed to be interchangeable, and the specific buffer car and escort car designs to be used in SNF transportation are outside this scope of work.

2. INITIAL EFFORTS

A contract was awarded in February 2019 to execute the 8-axle railcar work scope. Phase 1 of that contract is currently (May 2019) in progress. The deliverables under Phase 1 include:

- The cask railcar conceptual design, including the sizing and location of the structural components and all the locations of necessary components of the spent fuel rail cask design that are needed to meet the performance requirements. These particulars are addressed in detail in AAR Standard S-2043, Sections 3.1, 3.2 and Section 4.0-4.2.4, which include all the design aspects prior to multibody dynamic modeling. As already noted, the cask railcar must be designed with eight or fewer axles to minimize the capital costs of production cask railcars.

- Conceptual description and drawings of the mechanism to attach the cradles to the rail car. These will be subject to the AAR Field Manual Rule 88 [4] loading criteria of 7.5g (longitudinal), 2g (vertical), 2g (lateral) as shown in paragraph 16.c(3) thereof.

Also, as defined in the statement of work for this effort, the cask railcar must be designed to carry each of the spent fuel casks identified in Table 1. During transport, the transportation casks must rest on a cradle, often called a skid, on top of the cask railcar deck. The cask railcar must be designed to transport one cask at a time, along with one cask cradle. The cask railcar design must include attachment points to the deck. For this effort, the cradle/cask attachment system proposed is shown in [5&6]. This reference is to be used to maintain consistency between the new 8-axle railcar design and the 12-axle railcar design (called 'Atlas') that is currently under development. Phase 2 of the Atlas railcar work included a preliminary design of the prototype railcars and dynamic modeling results of the Atlas and buffer railcars as well as the receipt of the AAR's notice to "proceed with the test phase" [6]. The Atlas railcar development work is proceeding as expected, and the 8-axle railcar development task is leveraging what was learned in the Atlas railcar development to help advance the 8-axle railcar effort.

Note that, as described above, the phases of the 8-axle railcar development task are different from the Atlas design task because the nature of the work is different. The 12-axle Atlas railcar is proceeding through the AAR certification process and is intended to be a viable SNF transportation option. The 8-axle railcar is being considered as a cost-effective alternative to the larger Atlas railcar. The 8-axle railcar task must first demonstrate conceptual feasibility in Phase 1 before the later phases (design optimization and design finalization) are authorized to proceed. If the design fails to achieve DOE approval at the end of any of the three phases, the 8-axle design will be halted.

The current status of the 8-axle railcar design task is that Phase 1 is proceeding as planned. There are a number of viable concepts under consideration, but it is premature to describe them in detail. It is anticipated that the end of Phase 1 will include a down-select from a number of potentially viable options to a single most promising concept for development in the later phases. The end of Phase 1 is also a decision point for DOE to decide whether or not to proceed to Phase 2 with any of the concepts. This key decision is expected to be made in the July 2019 timeframe.

3. FUTURE EFFORTS

After the completion of Phase 1, the Phase 1 conceptual design will be used to model and optimize the performance parameters of the conceptual design in Phase 2. This work will include all of the different casks shown in Table 1 to show that the cask railcar will perform within the performance criteria established by the AAR Standard S-2043.

Activities associated with Phase 2 include:

- Computer modeling/simulation input and output files for the structural analyses, static, and dynamic analyses, including detailed descriptions of design changes made as a result of modeling and analysis activities.
- All the necessary modeling of the railcar to show that with the anticipated loads the cask rail car will carry, it will meet all the performance requirements.
- A mature conceptual design and information necessary to fabricate the cask loads needed for testing the cask car as determined in the design analysis and simulations.
- A modified conceptual description and drawings of the mechanism to attach the cradles to the cask car, taking into account changes made during Phase 2.
- Railcar operation and maintenance information, including attention given in the design for railcar reliability, maintainability, and quality assurance requirements.

After receipt of DOE's approval to proceed with Phase 3 activities, a final design of a cask car, as described in Section 4.0 of AAR Standard S-2043, must be developed. This and the Phase 1 and 2 work will be summarized in a Preliminary Design Submittal to the AAR Engineering Equipment Committee (EEC), as outlined in S-2043 Sections 4.7-4.7.9.2 (neglecting 4.7.8-4.7.8.3, System Safety Monitoring).

At the end of Phase 3, it is required to receive from the AAR EEC notification to "proceed with the test phase," as stated in Paragraph 3.2.1 of Standard S-2043. Additionally, the final design must include all deliverables and information necessary to have one full-scale prototype cask car go out to bid to a fabricator.

Aspects associated with the final design include:

- Final Design Submittal, conforming to Section 4.7 of S-2043, as approved by AAR EEC.
- Computer modeling/simulation input and output files for the structural analyses, non-structural static analyses, and dynamic analyses.
- A copy of the AAR EEC notification to "proceed with the test phase"; along with any supporting documentation from AAR EEC.
- A complete set of technical specifications and procedures for all special processes needed to complete fabrication and assembly (i.e. welding, heat treatment, etc.).
- An inspection plan suitable for use by a third party to verify the fabrication and assembly of the cask car systems meets the design specifications.
- Cost and schedule estimate for the testing phase.

- Cost estimate and schedule for a production run of 120 cask cars.

As with the other phases, the end of Phase 3 will be a natural decision point for DOE to determine if the 8-axle railcar design is worth pursuing The requirements for Phase 3 include all additional information needed by DOE to make a cost benefit analysis for producing and maintaining a fleet of railcars that includes both 8-axle and 12-axle railcars.

4. CONCLUSIONS

This paper describes a three-phase design and development process for an 8-axle railcar for hauling SNF in the USA. The phased structure of this task allows DOE to assess the status of the design task at increments and decide if future investment in later steps is warranted. The 12-axle Atlas railcar is a number of steps ahead in the design and development process, so it serves as model for comparison. DOE's primary question is whether or not an 8-axle railcar is feasible, and this task is designed to answer that question. This task can be halted at the end of any of the three phases if an 8-axle design is not feasible.

DOE's next question is whether or not there is a significant benefit to producing both 8 and 12 axle railcars, and this task is designed to provide the information needed to make that conclusion at the end of Phase 3. Fabricating a prototype and conducting testing is outside the scope of this task, so DOE will make the decision to proceed with prototype fabrication and testing after this task is concluded.

TABLE 1. TRANSPORT CASK CHARACTERISTICS (NOMINAL CHARACTERISTICS OF SPENT NUCLEAR FUEL TRANSPORTATION CASKS)

Manufacturer and Model	**Length without Impact Limiters (in.)**	**Length with Impact Limiters (in.)**	**Diameter without Impact Limiters (in.)**	**Diameter with Impact Limiters (in.)**	**Empty Weight with Impact Limiters (lb.)**	**Loaded Weight with Impact Limiters (lb.)**
NAC International						
NAC-STC	193.0	273.7	99.0	128.0	188,767-194,560	241,664 – 254,589
NAC-UMS UTC	209.3	273.3	92.9	124.0	178,798	248,373-255,022
MAGNATRAN	214.0	322.0	110.0	128.0	208,000	312,000
Holtec International						
HI-STAR 100	203.25	307.5	96.0	128.0	179,710	272,622- 279,893
HI-STAR HB	128.0	230.8[a]	96.0	128.0[a]	--[b]	187,200

HI-STAR 180	174.37	285.04	106.30	128.0	< 308,647	308,647
HI-STAR 60	158.94	274.37	75.75	128.0[a]	<164,000	164,000
HI-STAR 190 SL	214.4688	339.5625	106.5[e]	128	282,746	369,049-382,746[f]
HI-STAR 190 XL	236.9688	362.0625	106.5[e]	128	304,369	Up to 420,769
AREVA Transnuclear						
MP187	201.5	308.0	92.5	126.75	190,200	265,100-271,300
MP197	208.0	281.25	91.5	122.0	176,710	265,100
MP197HB	210.25	271.25	97.75	126.0	179,000	303,600
TN-32B[c]	184.0	261.0[a]	97.75	144.0[a]	--[d]	263,000[a]
TN-40	183.75	261.0	99.52	144.0	--[d]	271,500
TN40HT	183.75	260.9	101.0	144.0	--[d]	242,343
TN-68	197.25	271.0	98.0	144.0	<272,000	272,000
Energy*Solutions*						
TS125	210.4	342.4	94.2	143.5	196,118	285,000

Source: Reference 7

a. Estimated.
b. HI-STAR HB transportation casks are already loaded so they would not be shipped empty.
c. This is the TN-32B that DOE plans to use in the High Burnup Dry Storage Cask Research and Development Project, and ship from North Anna Nuclear Power Plant. The TN-32B does not currently have a transport certificate of compliance. The dimensions and weight with impact limiters for the TN-32B are estimated.
d. TN-40 transportation casks are authorized for single use shipments and would not be shipped empty. TN-32B and TN40HT transportation casks are also assumed to be authorized for single use shipments and would not be shipped empty on an S-2043 cask car.
e. Diameter is of cask body and does not include trunnions.
f. Weights do not include the weights of any MPC spacers that may be required.

5. REFERENCES

[1] Performance Specification for Trains Used to Carry High-Level Radioactive Material, Standard S-2043 (Last revised 2017)

[2] 10 CFR 71, Packaging and Transportation of Radioactive Material

[3] ORNL - AAR S-2043 Cask Railcar System Requirements Document, FCRD-NFST-2014-000093 Rev.1, ORNL/TM-2014/596, December 1, 2014

[4] American Association of Railroads Field Manual of the AAR Interchange Rules – Rule 88 – Mechanical Requirements for Acceptance, 2019

[5] Design and Prototype Fabrication of Railcars for Transport of High-Level Radioactive Material, Phase 1: Mobilization and Conceptual Design, DE-NE0008390, October 2016, AREVA Federal Services, LLC.

[6] Design and Prototype Fabrication of Railcars for Transport of High-Level Radioactive Materials, Phase 2: Preliminary Design, DE-NE0008390, March 2018, AREVA Federal Services, LLC

[7] Greene, S.R., J.S. Medford, and S.A. Macy, Storage and Transport Cask Data for Used Commercial Nuclear Fuel, 2013 U.S. Edition, Report ATI-TR-13047, August 2013

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