WASTE ACCEPTANCE CRITERIA FOR THE DOE'S VITRIFIED HIGH-LEVEL WASTE FORM

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ABSTRACT

Borosilicate glass from Defense HLW producers will be emplaced in the civilian radioactive waste repository. Vitrified HLW will be under production before the repository license application is submitted. The DOE Office of Civilian Radioactive Waste Management (OCRWM) has therefore instituted the Waste Acceptance Process, which is a sequence of documentation whereby the DOE is assured that the high-level waste is vitrified in a consistent manner, and that adequate information is available about the final glass waste form to allow repository performance assessments to be made after production. An earlier methodology of information flow between DOE-HQ and the Waste Producers is being incorporated into the current Systems Engineering-based approach for identifying top-level requirements. This paper will describe those characteristics of the glass waste form relevant to acceptance into the Federal Waste Management System, the development of product specifications reflecting these characteristics, and the strategies used by the glass producers to assure compliance with acceptance specifications. It will also discuss the implementation of current DOE policy regarding the evolution of Waste Acceptance Process documentation.

INTRODUCTION

The Need for a Waste Acceptance Process

The high-level waste (HLW) resulting from defense and commercial reprocessing activities is to be disposed of, along with commercial spent nuclear fuel (SNF), in an NRC-licensed geologic repository. On direction from Congress, the DOE is currently evaluating the Yucca Mountain site for suitability as a potential repository.

The Defense Waste Processing Facility (DWPF) at the Savannah River Site in South Carolina, and the West Valley Demonstration Project (WVDP) in New York have chosen borosilicate glass as the waste form for their liquid HLW. Construction of the DWPF is complete, and the plant will start full-scale "cold" testing shortly. Construction of the WVDP is almost complete, and is about 2 years behind the DWPF in schedule. The Hanford Waste Vitrification Plant (HWVP) in Hanford, Washington, has also selected borosilicate glass as the final waste form for its liquid HLW, and has begun plant construction.

It should be noted that the DOE Office of Civilian Radioactive Waste Management (OCRWM) is responsible for repository licensing and cask certification, whereas radioactive waste vitrification processes are under the purview of the DOE Office of Environmental Restoration and Waste Management (OERWM). These two separate Offices are often referred to as "RW" and "EM" respectively. Since borosilicate glass from DWPF and WVDP, and possibly also from HWVP, will be under production before a repository license application is submitted to the NRC, the DOE will not yet have completed performance assessment of the glass products under repository conditions until after glass production is underway. As a result, RW has instituted the Waste Acceptance Process, which is a structured sequence of documentation whereby RW is assured that EM vitrifies the HLW in a consistent manner, and that adequate information is available about the final glass waste form to allow repository performance assessments to be made after glass production.

This paper discusses the evolution of DOE policy regarding the acceptance of the borosilicate glass waste form into the Federal Waste Management System.

SOME HISTORY

The Waste Acceptance Preliminary Specifications (WAPS)

Preliminary requirements for the acceptance of borosilicate glass were initially developed by OCRWM in the *Waste Acceptance Preliminary Specifications (WAPS)*, which placed on the vitrified waste form producers (DWPF in Savannah River and WVDP in New York) certain production-related specifications (such as canister weight and dimensions), as well as requirements to provide OCRWM with information on waste form characteristics (such as short-term durability, radioactivity content, etc). The *WAPS* identified the minimum technical specifications and data requirements to ensure that the waste form would be characterizable for repository purposes.

In accordance with the Waste Acceptance Process, the waste producers respond to the *WAPS* with technical documents - the *Waste Form Compliance Plan (WCP)*, the *Waste Qualification Report (WQR)*, and the *Production Records*

(PRs) and Shipping and Storage Records - which assure OCRWM of producer compliance with the *WAPS*.

The *WCP* identifies the specific tests and procedures, including those specified by RW, to be used to demonstrate compliance with the *WAPS*. The results from these tests and related analyses are compiled in the *WQRs*. The *WQRs* contain information on the waste form itself and on the production process, such as process controls, limits on ranges of variability, quality assurance, and demonstrations that the actual waste product meets the product specifications, will be consistently and verifiably produced by the reference process, and is representative of waste forms tested in the repository test program. A Waste Acceptance Technical Review Group (TRG) has been established by EM to provide independent formal technical reviews of the *WCPs* and *WQRs* from the individual vitrification facilities.

The *WAPS* was not intended to be a formal design specification document. The *WAPS* was an early effort by RW to assist in EM's glass production control in order to address certain repository information needs regarding the HLW waste form. As the Waste Acceptance Process has evolved, RW has since refined its technical requirements and has developed systems-level baseline documentation (for example, the *Physical System Requirements - Accept Waste (PSR-AW)* and the *Waste Acceptance System Requirements Document (WA-SRD)* that incorporate the requirements from the *WAPS* into the top-level requirements documentation. The systems engineering methodology used to develop these documents establishes a traceable flow-down of requirements from the top-level *PSR-AW* document into all lower-level documents. In turn, the *WA-SRD* will provide the required traceability between the regulatory requirements (as spelled out in the *PSR-AW* document) and the physical characteristics and programmatic responsibilities for waste acceptance for the vitrified HLW form. In addition, EM is currently developing its own set of product-related criteria based on the *WAPS*; this document is currently in draft form. The development of this document will be consistent with the *WA-SRD*. The respective roles of these new documents in the Waste Acceptance Process Documentation Hierarchy are discussed below.

CRWMS TECHNICAL BASELINE

The documentation of the Civilian Radioactive Waste Management System (CRWMS) technical baseline is consistent with DOE Orders and good engineering practice. Figure 1 depicts the general nature of the technical baseline documentation as it evolves with the major stages of facility design. This flow diagram is applicable to the design of any facility.

The overall objectives of baselining requirements under the system engineering approach are to:

1. ensure traceability of requirements from the top-level regulatory or statutory sources,
2. provide for the allocation of requirements to successively lower-level elements of the system,
3. integrate among subsystems through identified interfaces, and
4. establish methods for requirements conformance.

At the Program-level, the CRWMS is comprised of 4 system elements: waste acceptance, transportation, storage, and disposal. Close integration between each of the elements is essential, especially since each is at a different stage of design.

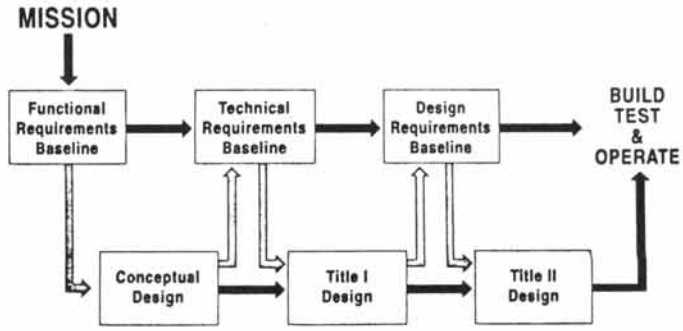

Fig. 1. Systems engineering approach in the CRWMS technical baseline.

Currently, the waste acceptance system element does not involve separately-designed physical facilities; in other words, the waste acceptance function is primarily administrative. However, documentation for the waste acceptance system is developed consistently with that of physical CRWMS facilities. This is due to the fact that several acceptance-related functions (e.g., verification and on-site handling) will parallel those in other system elements, and also that the SNF and canistered HLW are the prime physical interfaces within the CRWMS.

Each baseline document is developed through a consistent process, which is established in the Technical Document Preparation Plan for the Development of System Requirements Documents. The documents are prepared by a team of experts representing key aspects of the particular element. After informal reviews are completed, the document undergoes a Technical Document Review, in accordance with OCRWM Quality Assurance Procedures. Finally, the document is submitted for baselining to the Program Baseline Change Control Board (PBCCB). The PBCCB, comprised of the Directors from each of the OCRWM offices, ensures that baseline documents are controlled and that changes to the baseline are evaluated before their approval.

THE OCRWM SYSTEMS ENGINEERING APPROACH

Physical System Requirements Accept Waste Document (PSR-AW)

Waste acceptance is one of the system elements whose requirements have been baselined and controlled in the *Physical System Requirements - Accept Waste (PSR-AW)* document. The *PSR-AW* lists the top-level program requirements from external requirements source documents, such as statutes (NWPAA etc), regulations (10 CFR 60 and 71, etc), and DOE Orders. The *PSR-AW* covers requirements applicable to all waste acceptance activities and processes; these fall into three general areas.

The first area represents those requirements directly applicable to the waste form which are established external to OCRWM. The second area represents those requirements developed internal to OCRWM, which are based on interpretations of external requirements or established as OCRWM policy, that are directly applicable to the waste form. The third requirements category is derived from those requirements incumbent on other system elements, such as transportation or disposal, which require documented information on the waste form characteristics in order to provide "source term" information for the other system elements.

As part of the natural evolution of requirements documents, the *PSR-AW* is to be superseded by the *Waste Acceptance System Requirements Document (WA-SRD)*, which will contain more detailed requirements, lower-level interpretations, and conformance and traceability information. The *WA-SRD* is described below.

RECENT DEVELOPMENTS

Waste Acceptance System Requirements Document (WA-SRD)

The *CRWMS Requirements Document (CRD)* and the *Waste Acceptance System Requirements Document (WA-SRD)* represent the requirements baseline covering the waste acceptance function within the CRWMS. They were approved for baselining by the PBCCB on December 23, 1992.

The *CRD* identifies all external regulatory sources applicable to OCRWM and allocates them to the appropriate system elements. The *WA-SRD* documents the top-level requirements on the waste acceptance element. In addition, the *WA-SRD* allocates requirements to the waste Purchasers (i.e., generators of SNF) and Producers (HLW producers), principally to establish the interface between OCRWM and external entities.

Specific to the HLW producers, the *WA-SRD* allocates requirements to the producers which represent responsibilities for the producer or characteristics of the canistered HLW. These requirements are primarily interfaces between the Producer and the CRWMS. Due to the uniqueness of the waste acceptance element, there are both physical interfaces (i.e., the canistered HLW and its associated characteristics) and programmatic interfaces (e.g., reporting requirements complementing the receipt of HLW, and quality assurance).

The purpose of the waste acceptance baseline is not to design vitrification facilities, but rather to establish bounds on the characteristics of the HLW to determine its acceptability into the CRWMS and to quantify the physical interface envelope. Programmatically, the purpose is to establish the responsibilities of, and procedures for, the producer to provide written documentation and pay necessary fees. Thus the *WA-SRD* acts as an information interface with the CRWMS.

The requirements established in the *WA-SRD* include those from specific regulatory requirements on HLW and those that are derived from requirements on the CRWMS and applied to the producer or the waste. Regulatory or statutory requirements which place direct constraints on the waste producers or the waste forms are limited in the *WA-SRD*. The most obvious examples of these are the requirements in the Standard Contract (10 CFR 961), or the NRC requirements specific to design of HLW forms under 10 CFR 60.135. The NRC regulations require that waste forms must be consolidated, and not contain free liquids or combustibles.

Providing interpretations to the technical baseline, derived requirements allow the CRWMS to establish specific allocations to elements other than the system element to which the regulation actually applies. The derivations lead to the identification of detailed requirements for which specific facility designs or detailed procedures can be developed. The derivations can be technical, institutional, regulatory, or other interpretations which take a high-level, unquantified regulation or statute and produce a low-level, measurable specification. For the producer, the derived requirements represent those which need to be performed by the producer or by the canistered HLW in order for other system elements to meet their regulations. The following categorization of the major requirements on HLW glass help to clarify derived requirement development in the *WA-SRD*. Some of these requirements are subject to revision, and will be resolved in the future.

- **HLW Receipt Requirements**
  - The first repository is limited to a receipt of 7,000 MTU_{eq} of glass HLW
  - Acceptance is to begin in 2015
  - Defense HLW is to be shipped by rail to the repository
  - First repository is to accept 13,500 canisters of HLW glass

  Justification: These requirements are based on assumptions in the Mission Plan of 10% repository inventory, schedule, and modal split. The estimated number of HLW canisters for the first repository is key interface information needed for repository design.
- HLW Standard Form Requirements
  - Total HLW canister length shall be 3.0 meters
  - Canister diameter shall be 61.0 centimeters
  - Filled canister weight shall not exceed 2500 kg
  - Fill height shall be at least 80% of volume
  - Total heat generation not to exceed 1500 Watts
  - Glass temperature shall never have exceeded 400°C
  - Helium leak rate shall be less than $1x10^{-4}$ atm-cc/sec
  - No detectable free liquid or explosive material content in canister
  - Canister shall have a unique alphanumeric identifier

  Justification: This standard acceptable waste form establishes an interface with repository requirements. These requirements are based on existing facility designs and applicable section of 10 CFR Parts 60 and 71.
- General Characteristics Requirements
  - Canistered HLW dose limits at shipment shall not exceed 10^5 rem/hr (gamma) and 10 rem/hr (neutron)
  - Demonstration of the consistency of HLW glass is required through use of the Product Consistency Test (PCT) for Li, Na, B leach rates
  - Producer shall determine if the HLW has any RCRA listed wastes or characteristic components
  - Canistered HLW shall have no organic materials
  - Canistered HLW internal gas pressure less than 150 kPa

  Justification: The limits on these canistered HLW characteristics are necessary to ensure a bounding envelope for repository and transportation system design and regulatory compliance demonstrations.
- Transportation Interface Requirements
  - Producers to determine canister impact characteristics (drop test)

- External radiation on canister surfaces to be limited (wipe test)
- Producer shall design canister handling system for loading and unloading transportation casks
- HLW form shall be designed to avoid nuclear criticality

Justification: Transportation system design and cask routing needs depend on the ability of the canister to meet 10 CFR 71.63(b), and on the ability of the transportation system to meet the rest of 10 CFR Part 71. Modal splits are based on current CRWMS plans.

- Repository Interface Requirements
  - Radionuclide inventory to be reported for radionuclides present in concentrations greater than 0.05% of the total
  - HLW must be stored below 400°C at storage facility so as not to affect phase stability or integrity
  - Canister to have legible labeling through the period of lag storage at the repository

  Justification: Radionuclide inventory and phase information needed to conduct modeling of releases after repository closure. Canister labeling required to support repository labeling requirements applicable through the period of retrievability.
- Recordkeeping and Documentation Requirements
  - Producer shall document plans to show compliance with *WA-SRD* in *Waste Compliance Plan (WCP)*
  - Producer shall compile waste form testing results against *WA-SRD* in *Waste Qualification Report (WQR)*
  - Producer shall document actual canistered waste form characteristics in the *Production Records (PRs)*
  - Producer shall document the condition of the canistered waste forms at the time of shipment in *Storage and Shipping Records*

  Justification: Producer plans, reports, and records are necessary to document the characteristics of the HLW in accordance with requirements of the *WA-SRD* and QARD.
- Quality Assurance Requirements
  - Producer shall establish, maintain, and execute a quality assurance program consistent with the QARD
  - Producer's QA program shall cover all activities for structures, systems, and components important to safety
  - Producer shall maintain documentation for canistered waste form compliance as lifetime QA records

  Justification: These requirements are established in the QARD.

As an example of a technically derived requirement, the *WA-SRD* establishes a requirement for canister labeling. The basis for the requirement is 10 CFR Part 60, which requires the repository to ensure that waste package labels remain intact through the period of retrievability. Although this Part 60 requirement is allocated to the Mined Geologic Disposal System, the associated producer requirement in the *WA-SRD* establishes the producer's part of the "handshake" in order to meet this important NRC regulation.

The *WA-SRD* contains many requirements which were derived for administrative purposes. An example of these are the requirements on standard waste forms. The process for identifying standard, non-standard, and non-conforming forms was derived from requirements in 10 CFR 961 for spent fuel. Any canister of HLW which meets all specified characteristics is a standard waste form; the design of CRWMS facilities will be completely compatible with this type of waste. However, if any waste form cannot demonstrate compliance with any of the applicable WA-SRD requirements, the waste is considered non-conforming. If the non-conformance is due to one of a few requirements related directly to the acceptability of the waste (e.g., that could impact the mission of the repository or transportation system to meet its own system requirements), the waste may not be accepted into the CRWMS. Any other non-conformance would require disposition or correction of the waste form in order for it to be accepted as a non-standard form.

The current draft of the *WA-SRD* has established derived requirements primarily for the HLW producers. Requirements for spent nuclear fuel (SNF) for the waste acceptance element within OCRWM are principally extracted directly from statutes, regulations, and DOE Orders. Derivations for these will be developed in subsequent revisions of the *WA-SRD*.

For the majority of requirements, the *WA-SRD* identifies the method of compliance with each requirement. Conformance matrices establish a measurable or verifiable means for lower-level documents to demonstrate compliance. At the Program-level, these methods include analyses, demonstrations, tests, or inspection. For example, the canister labelling requirements can be satisfied upon inspection of the label integrity and demonstration of its legibility. The compliance strategy for those requirements allocated to the HLW or the waste producers must be detailed in EM-produced documents (i.e., the *WCPs* and *WQRs*, as will be outlined below). Within the means established for conformance in the *WA-SRD*, it allows the different waste producers sufficient latitude to comply with individual specifications according to their particular cases. (For example, in their *WCPs* and *WQRs* DWPF and WVDP have not presented the same strategies for complying with specifications such as glass product consistency and canister fill height.) In order to provide assurance that these differing strategies comply with the specifications, a Waste Acceptance Technical Review Group (TRG) has been established by EM to provide independent formal technical reviews of the *WCPs* and *WQRs* from the individual vitrification facilities.

DESIGN REQUIREMENTS BASELINE

The EM Waste Acceptance Product Specifications (EM-WAPS)

Within DOE, the EM Vitrification Projects Division is responsible for the oversight of the waste vitrification facilities. As mentioned earlier, EM will issue a baseline document, the *Waste Acceptance Product Specifications (EM-WAPS)*, which will provide the equivalent "Project-to-Program" technical interface. The *EM-WAPS* will specifically derive each

applicable requirement from the *WA-SRD* and may eventually include additional specifications necessary between EM and its field offices and contractors. The purpose of the *EM-WAPS* is to identify low-level specifications applicable to the waste producers, while ensuring traceability from the *WA-SRD*. As of January 1993, EM is performing a Technical Document Review on the *EM-WAPS*.

Additional EM documentation, originating from the earlier *WAPS* and carried forth in the *WA-SRD* and *OCRWM Quality Assurance Requirements and Description Documents*, will be provided by EM to demonstrate compliance with the *WA-SRD* requirements. This documentation, as described earlier, consists of 4 separate parts. Thus, the *Waste Form Compliance Plan (WCP)* will describe the strategy and approach for complying with the applicable requirements of the *WA-SRD*. It will be modified as the vitrification facility testing and operation progresses. The *Waste Form Qualification Report (WQR)* provides the results of tests, analyses, or other methods used to demonstrate compliance with the *WA-SRD*. At the time of production of each canistered HLW form, *Production Records* will be prepared which will detail the canistered HLW characteristics. Prior to acceptance of the waste within the CRWMS, the canistered waste will be stored on the vitrification site and prepared for shipment. The *Shipping and Storage Records* provide additional documentation on the contents and condition of the waste up until the time of acceptance. This EM documentation (*WCPs, WQRs, Production Records, and Storage & Shipping Records*) will respond to the *WA-SRD* (and eventually, to the *EM-WAPS*) as they did to the *OCRWM WAPS*.

Finally, it must be reiterated that OERWM (EM) and OCRWM (RW) are two distinct Offices within DOE. Furthermore, there are no members of the PBCCB representing OERWM. Because of this, there is a need to formalize the implementation of the joint technical baseline as part of the Waste Acceptance Process. The Process will clearly define the hierarchy of joint EM/RW technical documents, identify technical and programmatic reviews, and establish procedures on document distribution, purpose, and changes. Therefore, controls between the two DOE Offices need to be established in order to ensure that changes to the baselines of either Office are controlled and properly evaluated. This is normally accomplished under a MOA. Several MOAs between RW and EM are under various stages of development.

SUMMARY

DOE has developed a formal process for the production and acceptance of HLW which will undergo performance assessments required for permanent geologic disposal. The Defense Waste Processing Facility (DWPF) is currently performing a series of Start-up Tests. Most *WQR* Volumes need formal approval by the TRG for internal DWPF milestones to be met. The Technical Reviews by the TRG of these DWPF *WQR* Volumes (and the *WCP*) have proved to be an essential oversight element for DWPF start-up activities.

A top-down listing of the various Waste Acceptance Process documents, along with their originating entities, major functions, and current status, is provided below:

RW Documents

- Physical System Requirements - Accept Waste (PSR-AW): Top-level functional requirements document, developed by Systems-Engineering methodology. Enumerates the major direct regulatory and statutory requirements on the Waste Acceptance function, as well as requirements internally derived but directly applicable to the waste form or to the interfaces with other system elements. Approved for baselining by the PBCCB in December 1992, the *PSR-AW* will be superseded by the *WA-SRD*.
- Waste Acceptance System Requirements Document (WA-SRD): Allocates requirements to the Waste Producers, primarily as derivations or interpretations of top-level requirements from the *PSR-AW*. Requirements are primarily interfaces (both physical and programmatic) between the Producers and the CRWMS. The current draft of the *WA-SRD* has been approved for baselining by the PBCCB in December 1992. Subsequent revisions will also incorporate requirements on Spent Fuel.

EM Documents

- EM Waste Acceptance Product Specifications (EM-WAPS): Equivalent "Project-Level" requirements document, developed by OERWM (EM) Vitrification Projects Division. MOA between RW and EM will establish formal linkage with *WA-SRD*. Contains more detailed interpretations and derivations of the requirements from the *WA-SRD*, enabling specific facility design and detailed compliance procedures. Development is based on the *OCRWM WAPS*. As of January 1993, the first draft of the *EM-WAPS* is undergoing Technical Review.
- Waste Compliance Plans (WCPs): Developed by individual vitrification facilities, describes the strategies and approaches for complying with the applicable requirements of the *WA-SRD*. By the date of publication of this paper, the *WCPs* from Savannah River (DWPF) and West Valley (WVDP) will have been approved by EM.
- Waste Qualification Reports (WQRs): Detailed documents which provide the results of tests, analyses, or other methods used to demonstrate compliance with the *WA-SRD*. Essential *WQR* Volumes from the DWPF have been reviewed by the EM Technical Review Group (TRG), allowing commencement of full-scale Cold Qualification Runs. Further *WQR* volumes will incorporate data from the Cold Qualification Runs, and on approval by the TRG, will support start of radioactive operations. Subsequent to hot start-up, addenda to some *WQR* volumes will also require TRG review and approval.
- Production Records (PRs) and Storage & Shipping Records: These documents will be prepared by the vitrification facilities once HLW glass canisters are under production, and will detail the canistered HLW characteristics upon production and during interim storage until the time of shipment to the CRWMS.