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9801210017 - PART 3

TRW Environmental
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WBS: 1.2.2.2
QA: N/A

Contract #: DE-AC01-91RW00134
LV.WPD.VP.08/97-168

August 5, 1997

Dr. Stephan J. Brocoum
Assistant Manager for Licensing
Yucca Mountain Site Characterization
Office, M/S 523
P.O. Box 30307
North Las Vegas, NV 89036-0307

Subject: Completion of M&O deliverable WP220754 "EBS/WP Materials Selection Analysis" (WBS 1.2.2.2)

Dear Dr. Brocoum:

This letter is to document the completion of level 3 deliverable WP220754 EBS/WP Materials Selection Analysis due on August 15, 1997. A Design Analysis document titled " Waste Package Supports and Sorptive Inverts-Materials Selection" is attached.

Carbon steel was selected for the support materials. One of the key criteria used in the materials selection process for the waste package supports was compatibility with the corrosion allowance barrier of the waste package. It was concluded that selection of carbon steel for the support material would provide optimum compatibility while meeting strength and dimensional requirements derived from the conceptual design of the supports.

Two candidate materials, apatite and envirostone, were considered for the sorptive invert materials. While envirostone was not found to be an effective sorber for technetium, there are a number of uncertainties associated with the use of apatite as the sorber for neptunium. As a result, it is recommended that no sorptive invert additives be used at this time.

If you have any questions regarding this submittal, please contact me on (702) 295-5601.

Sincerely,

Richard D. Snell, Manager
Engineering and Integration Operations
Management and Operating Contractor

Enclosures:
1) Deliverable Acceptance Review (YAR)
2) Participant Planning Sheets
3) Design Analysis "Waste Package Supports and Sorptive Inverts- Materials Selection"

cc w/enclosures:
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K. A. Bhattacharyya, M&O, Las Vegas, NV
H. A. Benton, M&O, Las Vegas, NV
T. W. Doering, M&O, Las Vegas
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Doug Smith, M&O, Las Vegas, NV
David Stahl, M&O, Las Vegas, NV
Files: Deliverables

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CRWMS/M&O

Design Analysis Cover Sheet

Complete only applicable items.

(1.)

QA: NL

2. DESIGN ANALYSIS TITLE Waste Package Supports and Sorptive Inverts-Materials Selection			
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11. REMARKS

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PDR WASTE
WM-11 PDR

Design Analysis Revision Record

Complete only applicable items.

1.

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3. DOCUMENT IDENTIFIER (Including Rev. No.)

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4. Revision No.	5. Description of Revision
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1. Purpose

This analysis is prepared by the Mined Geologic Disposal System (MGDS) Waste Package Development department to provide documented justification for the materials selections for preliminary design of the waste package supports and sorptive invert materials. The objective of this analysis is to recommend materials for use in preliminary design of the waste package supports and sorptive inverts and to provide documentation of the preliminary selection and associated justification for these selections. Sorptive invert materials were included in this analysis as they are expected to contribute to the isolation of waste from the accessible environment.

This design analysis does not address post closure performance of the waste package supports because the post closure performance requirements for the supports are still TBD (to be determined). This aspect of the design will be addressed in future design analyses.

2. Quality Assurance

The Quality Assurance program applies to this analysis. The work reported in this document is part of the preliminary design of the engineered barrier segment. This activity can affect the proper functioning of the Mined Geologic Disposal System waste package; the waste package has been identified as an MGDS Q-List item important to safety and waste isolation (Ref. 5.1, pp. 4, 15). The waste package is on the Q-List by direct inclusion by the Department of Energy (DOE); a Quality Administrative Procedure QAP-2-3 evaluation has yet to be conducted. This work is subject to requirements of the *Quality Assurance Requirements and Description* (Ref. 5.3).

All design inputs which are identified in this document are for preliminary design process, and, excluding the codes and standards, shall be treated as unqualified data. These design inputs will require subsequent qualification (or superseding inputs) as the waste package design proceeds. This document will not directly support any construction, fabrication or procurement activity and therefore does not require TBV (to be verified) tracking. However, use of any data from this analysis for input into documents supporting procurement, fabrication, or construction is required to be controlled with TBV tracking in accordance with the appropriate procedures.

3. Method

The method used in this analysis is as follows. The requirements that are applicable to each component are identified based on a preliminary design of the supports. Materials characteristics are selected that will help meet those requirements. The candidate materials are rated against grading scales for these characteristics and suitable weighting factors are applied, according to the importance of the criteria in assuring that the component will perform its functions. This assures that material chosen is the most appropriate for the design. The following paragraphs describe the process in more detail.

Single types of waste package support and sorptive invert material are considered. The support is designed to accommodate waste packages of a variety of sizes, and the active invert material will be a bulk granular material, so its selection does not depend on the waste package type.

Quantitative performance requirements have not yet been assigned to the waste package supports and sorptive invert (Ref. 5.6, p. 3-54 and 3-55, EBDRD). However, these components can contribute to meeting more general requirements on the engineered barrier segment.

For the waste package supports, candidate materials are chosen from common engineering materials; for the sorptive invert, candidate materials are chosen from sorptive minerals. Selection criteria and grading scales are established, and a weighting factor (level of importance) is assigned to each criterion. In choosing the weighting factors, qualitative arguments are used to justify estimates of the importance of the criteria in assuring that the component will perform its functions. To determine the overall performance of the material, the expected performance of the material is determined for each criterion. For each criterion, a utility score is assigned to each material. The utility score can vary from zero (lowest performance) to the weighting factor (highest performance). The highest possible score is therefore equal to the sum of the weighting factors. Total utility scores for each material are calculated by adding the individual utility scores. This mathematical procedure follows that used in reference 5.80. For sorptive materials only qualitative criteria are used.

The following selection criteria were identified as contributing to the performance of materials for waste package supports:

Mechanical strength (yield strength)
Absorbed energy
Compatibility with waste package materials

The following selection criteria were identified for the sorptive invert:

Effectiveness of sorption
Cost

Correspondence between the selection criteria and the functions, and descriptions of how the criteria are applied to each component, are discussed in Section 7.1. Weighting factors, details of the application of the selection criteria, and grading scales are developed within the analysis on the basis of the expert opinion of the author.

The analysis given here has distinct limitations. In particular, the environment of these components is uncertain, and the performance of the components is correspondingly uncertain. However, these limitations do not provide a reason for dismissing the method; they apply to any method that involves prediction. The situation is well summarized by Title 10, U.S. Code of Federal Regulations, Part 60.101(a)(2): "Proof of the future performance of engineered barrier systems and the geologic setting over time periods of many hundreds or many thousands of years

is not to be had in the ordinary sense of the word.... What is required is reasonable assurance." In view of that, materials whose performance has been predicted (through a combination of analyses and tests) to be acceptable, have been sought, but no guarantee of performance can be provided. It is noted that the work presented here has not been subjected to peer review. During later stages of design, such a review may be helpful in developing consensus and showing reasonable assurance that the performance objectives will be met.

Materials specifications or other sources of information might be written in SI units, U.S. customary units, or both. For example, steel bar might be ordered to specifications of the American Society for Testing and Materials (ASTM) according to either the designation ASTM A 36 or the designation ASTM A 36M (Ref. 5.5). In the latter designation, "M" denotes a metric (SI) standard. For consistency, all the material specifications used herein are the versions written in U.S. customary units.

Many different systems are used to designate materials. For the purposes of this analysis, ASTM specifications are used whenever possible to denote the candidate materials. For minerals, however, ASTM specifications are generally not applicable.

Selection of materials for long-term testing, modeling, and performance assessment is beyond the scope of the present analysis. The results of such testing, modeling, and performance assessment should provide the basis for future confirmation or revision of the recommendations in this analysis.

4. Design Inputs

As mentioned in Section 2, all design inputs that are identified in this document are for preliminary stage design of the design process; all of these design inputs should be recognized as TBV but are not required to be controlled as TBV per NLP-3-15.

4.1 Design Parameters

Material Properties

Conversion factor: 1 ksi = 6.894757 MPa (from ASTM Std. E 380).

Waste Package Corrosion Allowance Material: carbon steel, ASTM A 516 (Ref. 5.80)--TBV

Waste Package Supports

The following materials specifications were selected as most appropriate based on the preliminary design of the supports (Ref. 5.8)

ASTM A 36 plate and round bar (carbon steel- see reference 5.5)

yield strength, min. -- 36 ksi (248 MPa)
tensile strength, min. -- 68 ksi (min) (469 MPa)
elongation, min. -- 20% in 8 in. gage length

ASTM A 500 grade B shaped structural tube material (carbon steel- see reference 5.21)

yield strength, min. -- 46 ksi (317 MPa)
tensile strength, min. -- 58 ksi (400 MPa)
elongation, min. -- 23% in 2 in. gage length

ASTM A 501 structural tubing (carbon steel- see reference 5.22)

yield strength, min. -- 36 ksi (248 MPa)
tensile strength, min. -- 58 ksi (400 MPa)
elongation, min. -- 20% in 8 in. gage length

ASTM B 221 aluminum bar (see reference 5.51, table 2)

yield strength, min. -- 19 ksi (131 MPa)
tensile strength, min. -- 41 ksi (283 MPa)
elongation, min. -- 14% in 2 in. gage length

ASTM A 276 stainless steel bar, type XM-19, hot rolled (see reference 5.15, table 2)

yield strength, min. -- 60 ksi (414 MPa)
tensile strength, min. -- 100 ksi (689 MPa)
elongation, min. -- 30% in 2 in. gage length

ASTM A 213 austenitic stainless steel tubing type XM-19 UNS 325700 (see Ref. 5.9, table 4)

yield strength, min. -- 55 ksi (379 MPa)
tensile strength, min. -- 100 ksi (689 MPa)
elongation, min. -- 35% in 2 in. gage length

Maximum Equivalent Stress (seismic):

plate (applicable to bars)- 9.7 ksi (66.9 MPa)---TBV
tube-- 41.5 ksi (286.7 MPa)---TBV
pipe-- 21.4 ksi (147.8 MPa)---TBV

Sorptive invert materials (from Ref. 5.81)

Envirostone
Apatite

4.2 Criteria

A preliminary conceptual design for the waste package supports has been developed and the criteria used for the selection of materials documented here is in support of the design (ref. 5.8). The preliminary design has established dimensional and strength requirements and assumes a design life of about 150 years (through the retrievability period). As is discussed in Section 3 above, the approach taken here is to identify the materials that are believed to be the most appropriate for the design. Therefore, only those requirements that directly apply to materials selection are listed here. The requirements are taken from the *Engineered Barrier Design Requirements Document* (EBDRD) (Ref. 5.6 EBDRD). Traceability to higher-level requirements is documented in the EBDRD. In the quotations below, "TBD" denotes "to be determined" and "TBR" denotes "to be resolved." Based on the rationale that the conclusions derived by this analysis are for preliminary design that will not be used as input to documents supporting construction, fabrication, or procurement, the TBD and TBR designations will not be carried to the conclusions of this analysis.

4.2.1 "Engineered Barrier Segment structures, systems, and components important to safety shall be designed so that the effects of anticipated natural phenomena and environmental conditions will not interfere with necessary safety functions."

[EBDRD 3.2.6.1.A]

The preceding requirement is considered to the extent that the selection criterion "mechanical strength" favors materials for the waste package supports that can support large loads without significant plastic deformation and to the extent that the selection criterion "absorbed energy" favors materials for the waste package supports that will absorb large amounts of energy before failing.

4.2.2 "Natural phenomena and environmental conditions considered in the design shall include events and conditions such as earthquakes, humidity, temperature, sand, dust, and fungus, bacteria and algae. ...."

[EBDRD 3.2.6.1.B]

The preceding requirement is considered in that the service stresses for the support materials were derived for the seismic conditions.

4.2.3 "To the extent practicable, the Engineered Barrier Segment components shall be designed to incorporate the use of non-combustible and heat-resistant materials."

[EBDRD 3.2.6.2.2]

The preceding requirement is considered in that all of the candidate materials are non-combustible and heat-resistant.

4.2.4 The Engineered Barrier segment shall be designed to assist the geologic setting in meeting the performance objectives for the period following permanent closure. The Engineered Barrier segment shall be designed to assure that: (a) releases of radioactive material from the EBS and then through the geologic setting to the accessible environment following permanent closure conform to applicable environmental standards; (b) assuming anticipated processes and events, the release of radioactive material will be a gradual process; © containment of radioactive materials within the waste packages will be substantially complete (TBD) for a period to be determined by the NRC, but not less than 300 years nor more than 1000 years (TBR) after permanent closure and (d) the release rate of release of any radionuclide following containment period does not exceed 1 part in 100,000 per year of the inventory of that nuclide at 1000 years following permanent closure.---TBV

[EBDRD 3.7.A-3.7.E]

The preceding requirements has been considered to the extent that one of the key criteria in selecting support material is its compatibility with the waste package material. Such compatibility assures that the waste containment barriers not degraded by the support material.

4.2.5 "Packages for SNF and HLW shall be designed so that the in situ chemical, physical, and nuclear properties of waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting."

[EBDRD 3.7.1.A]

4.2.6 "The design of waste packages shall include, but not be limited to, consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions."

[EBDRD 3.7.1.B]

The preceding requirements are not specifically allocated to the waste package supports or invert. Nevertheless, the requirement is related to the waste package supports in that interactions of the waste package supports with the waste packages could degrade the waste packages. The requirement is considered to the extent that the selection criterion "compatibility with waste package materials" favors materials waste package support materials that will not degrade the waste packages or be degraded by them.

4.3 Assumptions

The following assumptions from the *Controlled Design Assumptions Document* (Ref. 5.7) were used in the development of this document:

> Key 011: Waste packages will be emplaced in-drift in a horizontal mode.---TBV

The assumption above is used in Sections 7.1 and 7.2 in that the analysis treats horizontal, drift-emplaced waste packages.

DCSS 037: Invert material will consist of concrete/crushed tuff material combination. Other material additives may be used as necessary. ---TBV

The assumption above is used in Section 7.2 in considering sorptive additives to the invert material.

> EBDRD 3.7.1.I: Containment of radioactive material within all but 10 of the Waste Packages shall be substantially complete for at least 3000 years after permanent closure of the geologic repository (i.e., fewer than 10 waste packages shall be breached within the first 3000 years after permanent closure of the geologic repository).---TBV

A related assumption is that the waste package supports must be designed to function during post closure for a period of (TBD) years.

The assumption above is used in Section 7.1 in selecting weighting factors for the criterion "compatibility with other materials" and in evaluating materials against this criterion. The related assumption will be addressed in future analyses.

The bases for the assumptions above are given in reference 5.7.

Based on the rationale that the conclusions derived by this analysis are for preliminary design that will not be used as input to documents supporting construction, fabrication, or procurement, any unqualified information contained in reference 5.7 will not be carried to the conclusions of this analysis.

4.4 Codes and Standards

The various references published by the American Society for Testing and Materials (Ref. 5.5, 5.9 through Ref. 5.79) are used as sources of information in the analysis.

5. References

5.1 *Q-List* (U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM), YMP/90-55Q, Rev. 4)

5.2 Reserved for future use.

5.3 *Quality Assurance Requirements and Description* (U.S. DOE OCRWM, DOE/RW-0333P, Rev. 7)

5.4 Reserved for future use.

5.5 ASTM A 36/A 36M-94, "Standard Specification for Carbon Structural Steel" (American Society for Testing and Materials, Philadelphia, PA)

5.6 *Engineered Barrier Design Requirements Document,* YMP/CM-0024 Rev. 0, ICN 1, Yucca Mountain Site Characterization Project

5.7 *Controlled Design Assumptions Document,* Document Identifier (DI) Number B00000000-01717-4600-00032 Rev. 4, ICN-1, Civilian Radioactive Waste Management System (CRWMS), Management and Operating Contractor (M&O)

5.8 *Waste Package Support and Pier Static and Seismic Analyses,* DI Number BBAB00000-01717-0200-00006, REV 00, CRWMS M&O

5.9 ASTM A 213/A 213M-95a, "Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes" (American Society for Testing and Materials, West Conshohocken, PA)

5.10 ASTM A 249/A 249M-96a, "Standard Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes" (American Society for Testing and Materials, West Conshohocken, PA)

5.11 ASTM A 268/A 268M-96, "Standard Specification for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service" (American Society for Testing and Materials, West Conshohocken, PA)

5.12 ASTM A 269-96, "Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service" (American Society for Testing and Materials, West Conshohocken, PA)

5.13 ASTM A 270-95a$^{\epsilon 1}$, "Standard Specification for Seamless and Welded Austenitic

Stainless Steel Sanitary Tubing" (American Society for Testing and Materials, West Conshohocken, PA)

5.14 ASTM A 271-96, "Standard Specification for Seamless Austenitic Chromium-Nickel Steel Still Tubes for Refinery Service" (American Society for Testing and Materials, West Conshohocken, PA)

5.15 ASTM A 276-96, "Standard Specification for Stainless Steel Bars and Shapes" (American Society for Testing and Materials, West Conshohocken, PA)

5.16 ASTM A 314-95, "Standard Specification for Stainless Steel Billets and Bars for Forging" (American Society for Testing and Materials, Philadelphia, PA)

5.17 ASTM A 450/A 450M-96, "Standard Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes" (American Society for Testing and Materials, West Conshohocken, PA)

5.18 ASTM A 479/A 479M, "Standard Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels" (American Society for Testing and Materials, Philadelphia, PA)

5.19 ASTM A 484/A 484M-94b, "Standard Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings" (American Society for Testing and Materials, Philadelphia, PA)

5.20 ASTM A 498-94, "Standard Specification for Seamless and Welded Carbon, Ferritic, and Austenitic Alloy Steel Heat-Exchanger Tubes with Integral Fins" (American Society for Testing and Materials, Philadelphia, PA)

5.21 ASTM A 500-93, "Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes" (American Society for Testing and Materials, Philadelphia, PA)

5.22 ASTM A 501-93, "Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing" (American Society for Testing and Materials, Philadelphia, PA)

5.23 ASTM A 511-96, "Standard Specification for Seamless Stainless Steel Mechanical Tubing" (American Society for Testing and Materials, West Conshohocken, PA)

5.24 Reserved for future use.

5.25 ASTM A 554-94, "Standard Specification for Welded Stainless Steel Mechanical Tubing"

(American Society for Testing and Materials, Philadelphia, PA)

5.26 ASTM A 564/A 564M-95, "Standard Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes" (American Society for Testing and Materials, Philadelphia, PA)

5.27 ASTM A 565-95, "Standard Specification for Martensitic Stainless Steel Bars, Forgings, and Forging Stock for High-Temperature Service" (American Society for Testing and Materials, Philadelphia, PA)

5.28 ASTM A 582/A 582M-95b, "Standard Specification for Free-Machining Stainless Steel Bars" (American Society for Testing and Materials, West Conshohocken, PA)

5.29 ASTM A 585-92, "Standard Specification for Aluminum-Coated Steel Barbed Wire" (American Society for Testing and Materials, Philadelphia, PA)

5.30 ASTM A 632-90, "Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service" (American Society for Testing and Materials, Philadelphia, PA)

5.31 ASTM A 666-96, "Standard Specification for Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar" (American Society for Testing and Materials, West Conshohocken, PA)

5.32 ASTM A 688/A 688M-96$^{\epsilon 2}$, "Standard Specification for Welded Austenitic Stainless Steel Feedwater Heater Tubes" (American Society for Testing and Materials, West Conshohocken, PA)

5.33 ASTM A 771/A 771M-95, "Standard Specification for Seamless Austenitic and Martensitic Stainless Steel Tubing for Liquid Metal-Cooled Reactor Core Components" (American Society for Testing and Materials, West Conshohocken, PA)

5.34 ASTM A 778-90a$^{\epsilon 1}$, "Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products" (American Society for Testing and Materials, West Conshohocken, PA)

5.35 ASTM A 789/A 789M-95, "Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service" (American Society for Testing and Materials, West Conshohocken, PA)

5.36 ASTM A 791/A 791M-94, "Standard Specification for Welded Unannealed Ferritic Stainless Steel Tubing" (American Society for Testing and Materials, Philadelphia, PA)

5.37 ASTM A 803/A 803M-96, "Standard Specification for Welded Ferritic Stainless Steel Feedwater Heater Tubes" (American Society for Testing and Materials, West Conshohocken, PA)

5.38 ASTM A 826/A 826M-95, "Standard Specification for Seamless Austenitic and Martensitic Stainless Steel Duct Tubes for Liquid Metal-Cooled Reactor Core Components" (American Society for Testing and Materials, West Conshohocken, PA)

5.39 ASTM A 831/A 831M-95, "Standard Specification for Austenitic and Martensitic Stainless Steel Bars, Billets, and Forgings for Liquid Metal Cooled Reactor Core Components" (American Society for Testing and Materials, Philadelphia, PA)

5.40 ASTM A 851-96, "Standard Specification for High-Frequency Induction Welded, Unannealed, Austenitic Steel Condenser Tubes" (American Society for Testing and Materials, West Conshohocken, PA)

5.41 ASTM A 908-96, "Standard Specification for Stainless Steel Needle Tubing" (American Society for Testing and Materials, Philadelphia, PA)

5.42 ASTM A 953-96, "Standard Specification for Austenitic Chromium-Nickel-Silicon Alloy Steel Seamless and Welded Tubing" (American Society for Testing and Materials, West Conshohocken, PA)

5.43 ASTM B 150-95a, "Standard Specification for Aluminum Bronze Rod, Bar, and Shapes" (American Society for Testing and Materials, Philadelphia, PA)

5.44 ASTM B 150M-95a, "Standard Specification for Aluminum Bronze, Rod, Bar, and Shapes (Metric)" (American Society for Testing and Materials)

5.45 ASTM B 169-95, "Standard Specification for Aluminum Bronze Sheet, Strip, and Rolled Bar" (American Society for Testing and Materials, Philadelphia, PA)

5.46 ASTM B 169M-88, "Standard Specification for Aluminum Bronze Plate, Sheet, Strip, and Rolled Bar (Metric)" (American Society for Testing and Materials, Philadelphia, PA)

5.47 ASTM B 210-95, "Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes" (American Society for Testing and Materials, Philadelphia, PA)

5.48 ASTM B 210M-95, "Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes (Metric)" (American Society for Testing and Materials)

5.49 ASTM B 211-95a, "Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod,

and Wire" (American Society for Testing and Materials, West Conshohocken, PA)

5.50 ASTM B 211M-95, "Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire (Metric)" (American Society for Testing and Materials, Philadelphia, PA)

5.51 ASTM B 221-96, "Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes" (American Society for Testing and Materials, West Conshohocken, PA)

5.52 ASTM B 221M-95a, "Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes (Metric)" (American Society for Testing and Materials, Philadelphia, PA)

5.53 ASTM B 234-95, "Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes for Condensers and Heat Exchangers" (American Society for Testing and Materials, Philadelphia, PA)

5.54 ASTM B 234M-95, "Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes for Condensers and Heat Exchangers (Metric)" (American Society for Testing and Materials, Philadelphia, PA)

5.55 ASTM B 236-95, "Standard Specification for Aluminum Bars for Electrical Purposes (Bus Bars)" (American Society for Testing and Materials, Philadelphia, PA)

5.56 ASTM B 236M-95, "Standard Specification for Aluminum Bars for Electrical Purposes (Bus Bars) (Metric)" (American Society for Testing and Materials, Philadelphia, PA)

5.57 ASTM B 241/B 241M-96, "Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube" (American Society for Testing and Materials, West Conshohocken, PA)

5.58 ASTM B 279-93, "Standard Test Method for Stiffness of Bare Soft Square and Rectangular Copper and Aluminum Wire for Magnet Wire Fabrication" (American Society for Testing and Materials, Philadelphia, PA)

5.59 ASTM B 313/B 313M-95, "Standard Specification for Aluminum and Aluminum-Alloy Round Welded Tubes" (American Society for Testing and Materials, Philadelphia, PA)

5.60 ASTM B 317-96, "Standard Specification for Aluminum-Alloy Extruded Bar, Rod, Tube, Pipe, and Structural Profiles for Electrical Purposes (Bus Conductor)" (American Society for Testing and Materials, West Conshohocken, PA)

5.61 ASTM B 345-96, "Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube for Gas and Oil Transmission and Distribution Piping Systems" (American Society for Testing and Materials, West Conshohocken, PA)

5.62 ASTM B 345M-96, "Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube for Gas and Oil Transmission and Distribution Piping Systems (Metric)" (American Society for Testing and Materials, West Conshohocken, PA)

5.63 ASTM B 404-95, "Standard Specification for Aluminum and Aluminum-Alloy Seamless Condenser and Heat-Exchanger Tubes with Integral Fins" (American Society for Testing and Materials, Philadelphia, PA)

5.64 ASTM B 404M-95, "Standard Specification for Aluminum and Aluminum-Alloy Seamless Condenser and Heat-Exchanger Tubes with Integral Fins (Metric)" (American Society for Testing and Materials)

5.65 ASTM B 429-95, "Standard Specification for Aluminum-Alloy Extruded Structural Pipe and Tube" (American Society for Testing and Materials, Philadelphia, PA)

5.66 ASTM B 479-95, "Standard Specification for Annealed Aluminum and Aluminum-Alloy Foil for Flexible Barrier Applications" (American Society for Testing and Materials, Philadelphia, PA)

5.67 ASTM B 483-95, "Standard Specification for Aluminum and Aluminum-Alloy Drawn Tubes for General Purpose Applications" (American Society for Testing and Materials)

5.68 ASTM B 483M-95, "Standard Specification for Aluminum and Aluminum-Alloy Drawn Tubes for General-Purpose Applications (Metric)" (American Society for Testing and Materials, Philadelphia, PA)

5.69 ASTM B 491/B 491M-95, "Standard Specification for Aluminum and Aluminum-Alloy Extruded Round Tubes for General-Purpose Applications" (American Society for Testing and Materials, Philadelphia, PA)

5.70 ASTM B 547/B 547M-95, "Standard Specification for Aluminum and Aluminum-Alloy Formed and Arc-Welded Round Tube" (American Society for Testing and Materials, Philadelphia, PA)

5.71 ASTM B 592-93, "Standard Specification for Copper-Zinc-Aluminum-Cobalt Plate, Sheet, Strip, and Rolled Bar" (American Society for Testing and Materials, Philadelphia, PA)

5.72 ASTM B 648-78, "Standard Test Method for Indentation Hardness of Aluminum Alloys by Means of a Barcol Impressor" (American Society for Testing and Materials)

5.73 ASTM B 865-96, "Standard Specification for Precipitation Hardening Nickel-Copper-Aluminum Alloy (UNS N05500) Bar, Rod, Wire, Forgings, and Forging Stock" (American Society for Testing and Materials, West Conshohocken, PA)

5.74 ASTM E 215-87$^{\epsilon 1}$, "Standard Practice for Standardizing Equipment for Electromagnetic Examination of Seamless Aluminum-Alloy Tube" (American Society for Testing and Materials, Philadelphia, PA)

5.75 ASTM E 426-92, "Standard Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys" (American Society for Testing and Materials, Philadelphia, PA)

5.76 ASTM F 138-92, "Standard Specification for Stainless Steel Bar and Wire for Surgical Implants (Special Quality)" (American Society for Testing and Materials, Philadelphia, PA)

5.77 ASTM F 899-95, "Standard Specification for Stainless Steel Billet, Bar, and Wire for Surgical Instruments" (American Society for Testing and Materials, West Conshohocken, PA)

5.78 ASTM F 1314-95, "Standard Specification for Wrought Nitrogen Strengthened-22 Chromium-12.5 Nickel-5 Manganese-2.5 Molybdenum Stainless Steel Bar and Wire for Surgical Implants" (American Society for Testing and Materials, Philadelphia, PA)

5.79 ASTM F 1586-95, "Standard Specification for Wrought Nitrogen Strengthened-21 Chromium-10 Nickel-3 Manganese-2.5 Molybdenum Stainless Steel Bar for Surgical Implants" (American Society for Testing and Materials)

5.80 Waste Package Materials Selection Analysis, DI Number BBA000000-01717-0200-00020 REV 00, CRWMS M&O

5.81 Waste Isolation Study, DI Number B00000000-01717-5705-00062 REV 00, CRWMS M&O.

5.82 Drift Invert Structural Design Analysis, BBDC00000-01717-0200-00001 REV 00.

5.83 Engineered Barrier System Performance Requirements Study Report, BB0000000-01717-5705-00001 REV 02.

6. Use of Computer Software

Worldwide Standards Service Plus, from Information Handling Services, version 96-12, was used to search for ASTM standards. This program is considered to be support software and therefore does not require verification and validation under QAP-SI-0, Computer Software Qualification.

7. Design Analysis

This section is divided into two subsections. The first subsection discusses materials selection for the waste package support; the second discusses the sorptive invert materials. Each of the following subsections treats one component. For each component, candidate materials are chosen, rating scales are described for each criterion, the materials are rated against the rating scales, and the resulting utility scores are used to determine the best materials.

The weighting factors, subdivisions of weighting factors within each selection criterion, details of the application of the selection criteria, and grading scales are based on the expert opinion of the author. The analysis has not received a formal peer review.

7.1 Waste Package Supports

7.1.1 Candidate materials

Candidate material classes for the waste package supports included aluminum, carbon steel, and austenitic stainless steel. These material classes were selected as being representative of common engineering metals. Nonmetals were considered to be inappropriate for this application because they are usually brittle and subject to breakage in the event of an accident during waste package emplacement operations.

Waste package supports may be constructed from several parts, and the parts may be made from different forms (e.g., tubing, bar). The different forms, in turn, are often subject to different specifications. As a result, it is not possible to choose a material class by comparing one specification against another. Instead, appropriate specifications were chosen for each part of the waste package support. The geometric design of the waste package support includes parts that would be manufactured from round bar (123.8 mm diameter), round tubing (168.3 mm outside diameter and 124.4 mm inside diameter), and rectangular tubing (Ref. 5.8). For each material class, separate scores were calculated for each specification, and the scores for each were totaled. The material class with the highest total score was selected.

For aluminum bar, the Worldwide Standards Service Plus database was searched for ASTM specifications with titles that matched "aluminum AND bar*". This search string requires that the title contain the word "aluminum" and a word that starts with the letters "bar" (e.g., bar, bars). The results of the search are shown in Attachment I, Table I-1. Of the standards listed, A 585, B

150, B 150M, B 169, B 169M, B 479, B 592, B 648, and B 865 were eliminated because they are false matches, that is, these specifications are actually not for aluminum bar. Specifications B 236, B 236M, B 279, and B 317 were eliminated because the titles indicate specialized services for these materials. Specifications B 211M and B 221M were eliminated because these are metric standards for which corresponding customary standards exist. The remaining specifications are B 211 and B 221.

For aluminum tubing, the same database was searched for ASTM specifications with titles that matched "aluminum AND tub*". This search string requires that the title contain the word "aluminum" and a word that starts with the letters "tub" (e.g., tube, tubes, tubing). The results of the search are shown in Attachment I, Table I-2. Of the standards listed, E 215 was eliminated because it is a false match. Specifications B 234, B 234M, B 317, B 345, B 345M, B 404, and B 404M were eliminated because the titles indicate specialized services for these materials. Specifications B 210M, B 221M, and B 483M were eliminated because these are metric standards for which corresponding customary standards exist. ASTM B 210 was eliminated because Table 2 of this specification gives a maximum wall thickness of 0.500 in., which is insufficient for the waste package supports (Ref. 5.8). Similarly, Table 2 of ASTM B 313/B 313M gives a maximum wall thickness of 0.125 in.; Table 2 of ASTM B 483 gives a maximum wall thickness of 0.500 in., and Table 2 of ASTM B 547/B 547M gives a maximum wall thickness of 0.500 in. ASTM B 429 Section 1.1 restricts sizes to those listed in Appendix X1 of the specification; these sizes are not right for the waste package support. ASTM B 491/B 491M, Section 1.1 specifies a maximum outside diameter of 0.750 in., which is insufficient for the waste package supports (Ref. 5.8). The remaining specifications are B 211, B 221, and B 241. Of the acceptable specifications listed here and in the preceding paragraph, ASTM B 221 was chosen because it covers all shapes required for the waste package support, whereas B 211 covers only bar, rod, and wire, and B 241 covers only pipe and tube.

As is evidenced by ASTM B 221, Table 2, the mechanical properties of aluminum alloys are significantly affected by temper. Long-term exposure to high temperatures, as is expected in an emplacement drift, may alter the temper by mechanisms such as recovery of cold work or coarsening of precipitates. To avoid uncertainty about loss of mechanical properties, only the O (annealed) temper was considered. ASTM B 221, Table 2 lists several alloys that are available in the O temper, but it gives minimum values of tensile strength, yield strength, and tensile elongation at failure only for alloys 1060, 1100, 3003, alclad 3003, 5083, 5086, 5454, and 5456. Of these alloys, 5456 was chosen because it has the best mechanical properties, that is, the highest values for both yield strength and absorbed energy. Here, "absorbed energy" defined as $\epsilon(\sigma_y + \sigma_t)/2$, where ϵ is the tensile elongation at failure, σ_y is the yield strength, and σ_t is the (ultimate) tensile strength. Justification for this measure of performance is given in Section 7.1.2.

The carbon steel specification considered here are those used in reference 5.8, ASTM A 36, A 500, and A 501.

For austenitic stainless steel bar, the Worldwide Standards Service Plus database was searched for ASTM specifications with titles that matched "(austenitic OR stainless) AND bar*". The results of the search are shown in Attachment I, Table I-3.

Specifications A 314, A 479/A 479M, A 565, A 831/A 831M, F 138, F 899, F 1314, and F 1586 were eliminated because the titles indicate specialized services for these materials. Specification A 484/A 484M was eliminated because it is a general specification, not a specification for a particular material. Specification A 666 was eliminated because it is for flat bar, whereas the waste package supports require round bar (Ref. 5.8). Specification A 564/A 564M was eliminated because it is for age-hardening stainless steels rather than typical austenitic stainless steels. Specification A 582/A 582M was eliminated because it does not provide minimum values of tensile strength, yield strength, and tensile elongation at failure. The remaining specification is ASTM A 276.

For austenitic stainless steel tubing, the Worldwide Standards Service Plus database was searched for ASTM specifications with titles that matched "(austenitic OR stainless) AND tub*". The results of the search are shown in Attachment I, Table I-4. Of the standards listed, A 268/A 268M, A 789/A 789M, A 791/A 791M, and E 426 were eliminated because they are false matches. (Specification A 789/A 789M is for ferritic/austenitic (i.e., duplex) alloys, not austenitic alloys.) Specifications A 249/A 249M, A 270, A 271, A 498, A 688/A 688M, A 771/A 771M, A 803/A 803M, A 826/A 826M, A 851, and A 908 were eliminated because the titles indicate specialized services for these materials. Specification A 269 was eliminated because it does not specify minimum values of tensile strength, yield strength, and tensile elongation at failure. Specification A 450/A 450M was eliminated because it is a general specification, not a specification for a particular material. Specifications A 511 and A 554 were eliminated because they give minimum values of tensile strength, yield strength, and tensile elongation at failure only for round tubing (ASTM A 511, Table 12; ASTM A 554, Table S2.1), and those requirements are supplementary, not standard. Specification A 632 was eliminated because it applies only to tubing with an outside diameter less than ½ in. (ASTM A 632, Section 1.1), which is too small for the waste package supports (Ref. 5.8). Specification A 953 was eliminated because it applies only to one fairly unusual high-silicon composition (ASTM A 953, Table 1), UNS Designation S70003. More common compositions such as UNS Designation S30400 (Type 304) are not treated in that specification. The remaining specifications are A 213 and A 778. Of these, A 213 was chosen because it covers many more compositions than does A 778, as can be seen from ASTM A 213, Table 2 and ASTM A 778, Table 1.

ASTM A 213 and ASTM A 276 both list numerous compositions. Except for Type TP347HFG in ASTM A 213, each austenitic type is uniquely identified by a UNS Designation. The UNS Designations that appear in both specifications are S20100, S20200, S20910, S30400, S30403, S30451, S30453, S30815, S30908, S30940, S31008, S31040, S31600, S31603, S31651, S31653, S31700, S31725, S31726, S32100, S34700, and S34800. Mechanical properties for these compositions were taken from ASTM A 213 Table 4 and ASTM A 276 Table 2, with

appropriate account being taken for the sizes of the components. For each composition listed above, the yield strength and failure energy were determined. According to ASTM A 213 Table 4, Type XM-19 (UNS designation S20910) has the highest yield strength and absorbed energy. According to ASTM A 276 Table 2, Type XM-19 (UNS designation S20910) has the highest yield strength (if it is in the as-hot-rolled condition and over 3 in. to 8 in. thick) or the highest absorbed energy (if it is in Condition A (annealed). This result points to Type XM-19 as the preferred composition. To provide the same tensile properties for both forms, ASTM A 276 Type XM-19 Condition A is selected for bar.

The following table summarizes the material specifications that were considered. The following sections compare these materials for each material class.

	Material class		
Form	Aluminum	Carbon Steel	Stainless Steel
Bar/plate	ASTM B 221 5456-O	ASTM A 36	ASTM A 276 Type XM-19 Condition A
Tubing/pipe, round	ASTM B 221 5456-O	ASTM A 501	ASTM A 213 Type XM-19
Tubing, rectangular	ASTM B 221 5456-O	ASTM A 500 Grade B	ASTM A 213 Type XM-19

7.1.2 Selection criteria and ratings

Three selection criteria have been used in evaluating waste package support materials: yield strength, absorbed energy, and compatibility with waste package materials.

An important function of the waste package supports is to keep the waste packages in a well-defined location throughout the period of retrievability. As a result of handling accidents or seismic event, there may occasionally be unusually large loads on the waste package supports. Should this happen, it is desirable that the support resist the loads without undergoing significant plastic deformation. The appropriate measure of such materials performance is the yield strength. If the loads are so large that the yield strength is exceeded, it is desirable that the supports should deform plastically and thus absorb energy but not fail.

Reference 5.8, Waste Package Support and Pier Static and Seismic Analysis includes an analysis of the expected stresses in the various structural members (tubes, plates, pipes) of the waste package supports under static and seismic service conditions. These stress values form the basis

for comparing the mechanical properties of the candidate materials. Table 7-4 of reference 5.8 provides the following values for the calculated stress levels (seismic) for the support materials.

Maximum Equivalent Stress (seismic):

plate (applicable to bars)-	9.7 ksi (66.9 MPa)
tube--	41.5 ksi (286.7 MPa)
pipe--	21.4 ksi (147.8 MPa)

It is not common for materials specifications to include a minimum energy for failure of a material. However, specification often include minimum values for three related mechanical properties: (ultimate) tensile strength, yield strength, and tensile elongation at failure. Significant plastic deformation begins at the yield strength. As deformation continues, the stress increases until the tensile strength is reached; at this point the material fails. The elongation at failure is the strain necessary to cause failure. An appropriate estimate of the energy absorbed by a unit volume of material is the elongation (strain) at failure times the average of the yield and tensile strengths: $\epsilon(\sigma_y + \sigma_t)/2$, where ϵ is the tensile elongation at failure, σ_y is the yield strength, and σ_t is the tensile strength.

The waste package supports contact and interact with the corrosion allowance barrier of the waste package, so compatibility of the waste package support material with the waste package material is significant. In a humid drift, the support could serve as a cathode and promote galvanic corrosion of the corrosion allowance barrier. Alternatively, the corrosion allowance barrier could serve as a cathode and promote galvanic corrosion of the waste package support. Both of these effects are undesirable. To prevent such interactions, the waste package support should be electrochemically similar to the corrosion allowance barrier.

On the basis of above discussion, following selection criteria and scores were selected.

Selection Criteria	Score	Comment
Support Materials		
yield strength	0 or 10	0 if σ_y < maximum service stress (Ref. 5.8, table 7-4) 10 if σ_y is ≥ maximum service stress (Ref 5.8, table 7-4)
absorbed energy (AE)	0 5 10	for AE < 5 ksi for 5 ksi≤ AE ≥ 10 ksi for AE > 10 ksi
compatibility with WP container materials	0 10	not compatible compatible

Using the above selection criteria and the expected service conditions, the candidate materials for the supports were evaluated. It is to be noted that stainless steel has the highest yield strength and absorbed energy, carbon steel ranks second on these criteria, and aluminum ranks third. In electrochemical interactions, a carbon steel support would be compatible with a carbon steel corrosion allowance barrier; an aluminum support would be attacked by galvanic corrosion; and a stainless steel support could cause galvanic attack of the corrosion allowance barrier. It is possible that a corrosion layer may develop between the carbon steel supports and the waste package which could potentially affect waste package retrievability. This, however, is highly unlikely in light of the dry high temperature conditions prevailing during this period.

Based on the above discussion and the material properties listed in Section 4.1, scores were calculated for each of the candidate materials and are shown in the following table.

Material	Yield Strength (ksi)		Absorbed Energy (ksi)		Compatibility		Total Score
	value	score	value	score	value	score	
Plates/Bars							
Aluminum 5456-0 ASTM B 221	19	10	4.2	0	no	0	10
Carbon Steel, ASTM A 36	36	10	11	10	yes	10	30
Stainless Steel-Type XM-19, (hot rolled) ASTM A 276	60	10	24	10	no	0	20
Tubing/Pipe, (round)							
Aluminum 5456-0 ASTM B 221	19	0	4.2	0	no	0	0
Carbon Steel, ASTM A 501	36	10	9.4	5	yes	10	25
Stainless Steel Type XM-19, ASTM A 213	55	10	27.1	10	no	0	20
Tubing (rectangular)							
Aluminum 5456-0 ASTM B 221	19	0	4.2	0	no	0	0
Carbon Steel, ASTM A 500 Grade B	46	10	12.0	10	yes	10	30
Stainless Steel Type XM-19, ASTM A 213	55	10	27.1	10	no	0	20

It is clear from the above table, carbon steel is the best waste package support material. It is, however important to note that material compatibility between the waste package support and the corrosion allowance material was used as a key criterion. Therefore, any changes to the design of the waste package containment material (e.g., ceramic coating on the carbon steel, or substitution of alloy 400 for carbon steel) will have a significant impact on the scores. This analysis needs to be repeated at any time changes to the waste package materials that are in contact with the supports are proposed and incorporated (Ref. 5.80).

7.2 Sorptive Invert Materials

7.2.1 Candidate materials

One of the designs (preliminary) for the invert segments call for the material to be precast concrete (Ref. 5.82). The segments each approximately 1.2 m long are placed end to end to form a continuous string over the length of the drift. The segments contain rails for the gantry which places the waste package in the drift. The primary function of the invert segments is to support the drift liner and facilitate the emplacement of the waste packages by the gantry. It has been suggested that additives to the invert segments or backfill materials be considered for the sorption of radionuclides. Candidate materials proposed at this time are envirostone and apatite (Ref. 5.81). Los Alamos National Laboratory (LANL) is investigating other materials as potential sorbers.

Envirostone is a manufactured gypsum based cementitious material that has a polymer component present, originally intended for use as a solidifying agent for aqueous radioactive waste. Apatite is a naturally occurring calcium phosphate-based mineral that also has various combinations and amounts of fluorine, chlorine, hydroxyl and carbonate. (Ref. 5.81, pp. 3-24 to 3-26).

7.2.2 Selection criteria and ratings

The sorptive invert is part of the engineered barrier segment, so it should contribute to control of release from the engineered barrier segment. A sensitivity analysis was conducted to establish whether a sorptive invert would have any significant effect on total system performance. This analysis indicated that the invert would have to be highly sorptive for very long periods of time to have any significant effect on repository performance (Ref. 5.83). To address this aspect of the sorptive invert, the criterion "effectiveness of sorption" is used.

No limits have been set on the price of the engineered barrier segment, but, for each component, a low price is preferable to a high price. The selection criterion "cost" is used to address the preference for a low price.

LANL conducted a series of sorption experiments to assess sorption potential of envirostone and

apatite. The main intent of these experiments was to present a formal analysis of the ability of these materials to retard the migration of ^{237}Np and ^{99}Tc from the repository to the accessible environment and to determine how much of these materials would be needed to obtain a significant reduction in dose for the two radionuclides. Apatite was found to have no sorption capacity for Tc but was identified as a promising sorber for Np. However, its total sorption potential for Np is undetermined at this time. Envirostone was found to have little capability for Np sorption. For Tc, the mineral acts as a low rate absorber with approximately 12 to 13 percent of the initial amount of Tc exposed to envirostone being absorbed. Alternative material such as MgO for Tc is being investigated by LANL.

Preliminary calculations have been carried out to determine the quantity of minerals that would be needed. These show that to absorb all of the available Tc, the amount of envirostone needed would be about 1100 cubic meters or a layer about 130 m deep under each waste package, which is not feasible. Therefore, it does not appear practical to pursue this option further (Ref. 5.81, p. 3-26).

For apatite similar calculations showed that about 5 cubic meters per waste package would be required to absorb all of the Np. This translates to about a 0.6 m deep layer which is feasible. However, more recent information suggests that the solubility of Np in water (representative of repository conditions) may be several orders of magnitude (at least 2) lower than previously estimated. In addition, there are several other uncertainties in the results. It is not clear if the presence of other actinides in the water expected from the spent fuel would reduce the sorption potential for Np. It is also possible that changes in water chemistry due to the presence of cementitious material such as precast concrete may reduce the solubility of Np in the water. Also, the effect of changes in water chemistry due to the presence of apatite and its impact on the corrosion behavior of waste container materials has not been determined. Further, the cost of adding a layer of apatite is estimated to range from $24 million for a 0.2 m thickness to $338 million for 1.2 m thickness (Ref. 5.81, p. 4-3).

There may be other concerns associated with the use of envirostone and apatite. Both these materials contain essential nutrients for microbial growth and activity. Adding either of these materials, especially phosphorus could significantly increase the consequences of microbial activity to corrosion, water chemistry, hydrology and radionuclide transport.

In view of the uncertainties in the sorption effectiveness and the cost of using apatite, it is recommended, at this time, that no sorptive material be used as additive to the precast concrete invert segments. It is, however recommended that additional studies be carried out on apatite and other alternate materials to resolve the uncertainties and to facilitate selection of a suitable sorptive material for use if warranted.

8. Conclusions

The analysis reported in this document is part of the preliminary design of the engineered barrier segment and is based on unqualified input data. Any use of data from this analysis for input into documents supporting construction, fabrication, or procurement should be controlled as TBV in accordance with appropriate procedures.

8.1 Support Materials

A list of candidate materials was developed by screening appropriate ASTM standards for aluminum, carbon steel and stainless steel. Selection criteria (mechanical strength, absorbed energy and compatibility) and weighting factors for evaluating the candidate materials were developed. Quantitative scores for each criterion for the materials were calculated and totaled. Based on the scores, carbon steel with the following specifications were selected as the best waste package supports:

Plates/bars - ASTM A 36
Tube/pipe, round -- ASTM A 501
Tube, rectangular -- ASTM A 500 Grade B

It is to be noted that compatibility with the carbon steel corrosion allowance barrier was a key criterion in the selection of carbon steel. Therefore, if any changes to the design of the carbon steel outer barrier (such as ceramic coating) is proposed, analysis reported in this document should be reevaluated.

8.2 Sorptive Materials

Two sorptive minerals, apatite and envirostone, were evaluated qualitatively against selection criteria for sorption effectiveness and cost. Use of envirostone as a sorptive additive to invert segments for sorbing Tc was found to be impractical in view of the large quantities (1100 cubic meters for each waste package) needed. In the case of apatite, there is evidence of significant potential for sorption of Np. However, the data available is limited and there are significant uncertainties associated with the effectiveness. In addition, incremental costs associated with use of apatite may be as high as $338 million. In view of this it was recommended that no sorptive additives be used at this time. It is, however, recommended that studies on the candidate sorptive materials continue to resolve the uncertainties.

9. Attachments

Attachment I, shows the results of search for ASTM standards for the candidate materials.

ATTACHMENT I

Table I-1. Results of the search for ASTM standards for aluminum bar in the Worldwide Standards Service Plus database

ASTM A585	Standard Specification for Aluminum-Coated Steel Barbed Wire (AASHTO M305)
ASTM B150 REVA	Standard Specification for Aluminum Bronze Rod, Bar, and Shapes
ASTM B150M REVA	Standard Specification for Aluminum Bronze, Rod, Bar, and Shapes (Metric)
ASTM B169	Standard Specification for Aluminum Bronze Sheet, Strip, and Rolled Bar
ASTM B169M	Standard Specification for Aluminum Bronze Sheet, Strip, and Rolled Bar (Metric)
ASTM B211 REVA	Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire
ASTM B211M	Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire (Metric)
ASTM B221	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
ASTM B221M	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes (Metric)
ASTM B236	Standard Spec. for Al Bars for Electrical Purposes
ASTM B236M	Standard Specification for Aluminum Bars for Electrical Purposes (Bus Bars) (Metric)
ASTM B279	Standard Test Method for Stiffness of Bare Soft Square and Rect. Cu and Al Wire for Magnet Wire Fabrication
ASTM B317	Standard Spec. for Al Alloy Extruded Bar, Rod, Tube, Pipe, and Structural Profiles for Electrical Purposes .....
ASTM B479	Standard Specification for Annealed Al and Al Alloy Foil for Flexible Barrier Applications
ASTM B592	Standard Specification for Copper-Zinc-Aluminum-Cobalt Plate, Sheet, Strip, and Rolled Bar
ASTM B648	Standard Test Method for Indentation Hardness of Aluminum Alloys by Means of a Barcol Impressor R(1994) 8000 Series Al alloy for Subsequent Covering or Insulation
ASTM B865 REVA	Standard Specification for Precipitation Hardening

ATTACHMENT I

Table I-2. Results of the search for ASTM standards for aluminum tube in the Worldwide Standards Service Plus database

ASTM B210	Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes
ASTM B210M	Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes (Metric)
ASTM B221	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
ASTM B221M	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes (Metric)
ASTM B234	Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes for Condensers and Heat Exchangers
ASTM B234M	Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes for Condensers and Heat Exchangers (Metric)
ASTM B241/B241M	Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
ASTM B313/B313M	Standard Specification for Aluminum and Aluminum-Alloy Round Welded Tubes
ASTM B317	Standard Specification for Aluminum-Alloy Extruded Bar, Rod, Tube, Pipe, and Structural Profiles for Electrical Purposes (Bus Conductor)
ASTM B345	Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube for Gas and Oil Transmission and Distribution Piping Systems
ASTM B345M	Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube for Gas and Oil Transmission and Distribution Piping Systems (Metric)
ASTM B404	Standard Specification for Aluminum and Aluminum-Alloy Seamless Condenser and Heat-Exchanger Tubes with Integral Fins
ASTM B404M	Standard Specification for Aluminum and Aluminum-Alloy Seamless Condenser and Heat-Exchanger Tubes with Integral Fins (Metric)
ASTM B429	Standard Specification for Aluminum-Alloy Extruded Structural Pipe and Tube
ASTM B483	Standard Specification for Aluminum and Aluminum-Alloy Drawn Tubes for General Purpose Applications
ASTM B483M	Standard Specification for Aluminum and Aluminum-Alloy Drawn Tubes for General-Purpose Applications (Metric)
ASTM B491/B491M	Standard Specification for Aluminum and Aluminum-Alloy Extruded Round Tubes for General-Purpose Applications
ASTM B547/B547M	Standard Specification for Aluminum and Aluminum-Alloy Formed and Arc-Welded Round Tube
ASTM E215	Standard Practice for Standardizing Equipment for Electromagnetic Examination of Seamless Aluminum-Alloy Tube (E1-1992) R(1992) Nickel-Copper-Aluminum Alloy (UNS N05500) Bar, Rod, Wire, Forgings, and Forging Stock

ATTACHMENT I

Table I-3. Results of search for ASTM standards for stainless steels in the Worldwide Standards Service Plus database

ASTM A276	Standard Specification for Stainless Steel Bars and Shapes
ASTM A314	Standard Specification for Stainless Steel Billets and Bars for Forging
ASTM A479/A479M REV B	Standard Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
ASTM A484/A484M REV B	Standard Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
ASTM A564/A564M	Standard Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes
ASTM A565	Standard Specification for Martensitic Stainless Steel Bars, Forgings, and Forging Stock for High-Temperature Service
ASTM A582/A582M REV B	Standard Specification for Free-Machining Stainless Steel Bars
ASTM A604	Standard Test Method for Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets
ASTM A666	Standard Specification for Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar
ASTM A831/A831M	Standard Specification for Austenitic and Martensitic Stainless Steel Bars, Billets, and Forgings for Liquid Metal Cooled Reactor Core Components
ASTM F138	Standard Specification for Stainless Steel Bar and Wire for Surgical Implants (Special Quality)
ASTM F899	Standard Specification for Stainless Steel Billet, Bar, and Wire for Surgical Instruments
ASTM F1314	Standard Specification for Wrought Nitrogen Strengthened - 22 Chromium - 12.5 Nickel - 5 Manganese - 2.5 Molybdenum Stainless Steel Bar and Wire for Surgical Implants
ASTM F1586	Standard Specification for Wrought Nitrogen Strengthened - 21 Chromium - 10 Nickel - 3 Manganese - 2.5 Molybdenum Stainless Steel Bar for Surgical Implants

ATTACHMENT I

Table I-4. Results of search for ASTM standards for stainless steel tubing in the Worldwide Standards Service Plus database

ASTM A213/A213M REVA	Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
ASTM A249/A249M REVA	Standard Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes
ASTM A268/A268M	Standard Specification for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service
ASTM A269	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A270 REV A	Standard Specification for Seamless and Welded Austenitic Stainless Steel Sanitary Tubing E1-1996
ASTM A271	Standard Specification for Seamless Austenitic Chromium-Nickel Steel Still Tubes for Refinery Service
ASTM A450/A450M	Standard Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes
ASTM A498	Standard Specification for Seamless and Welded Carbon, Ferritic, and Austenitic Alloy Steel Heat-Exchanger Tubes with Integral Fins
ASTM A511	Standard Specification for Seamless Stainless Steel Mechanical Tubing
ASTM A554	Standard Specification for Welded Stainless Steel Mechanical Tubing
ASTM A632	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service
ASTM A688/A688M	Standard Specification for Welded Austenitic Stainless Steel Feedwater Heater Tubes E1-1996; E2-1996
ASTM A771/A771M	Standard Specification for Seamless Austenitic and Martensitic Stainless Steel Tubing for Liquid Metal-Cooled Reactor Core Components
ASTM A778 REV A	Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products (E1-1995) R(1995)
ASTM A789/A789M	Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service
ASTM A791/A791M	Standard Specification for Welded Unannealed Ferritic Stainless Steel Tubing
ASTM A803/A803M	Standard Specification for Welded Ferritic Stainless Steel Feedwater Heater Tubes
ASTM A826/A826M	Standard Specification for Seamless Austenitic and Martensitic Stainless Steel Duct Tubes for Liquid Metal-Cooled Reactor Core Components
ASTM A851	Standard Specification for High-Frequency Induction Welded, Unannealed, Austenitic Steel Condenser Tubes
ASTM A908	Standard Specification for Stainless Steel Needle Tubing
ASTM A953	Standard Specification for Austenitic Chromium-Nickel-Silicon Alloy Steel Seamless and Welded Tubing
ASTM E426	Standard Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys