CRWMS/M&O

Design Analysis Cover Sheet

Complete only applicable items.

(1.) QA: ~~N~~ L

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2. DESIGN ANALYSIS TITLE			
ESF Ground Support - Material Dedication Analysis for Structural Steel and Accessories from a Commercial Grade Source			
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7. Originator	Marvin D. Stine	Marvin D. Stine	01/22/96
8. Checker	Matthew J. Gomez	Matthew J. Gomez	01/22/96
9. Lead Design Engineer	Malcolm E. Taylor, Jr.	MD Stine for M.E. Taylor	01/22/96
10. QA Manager	HYDE GRIFFITH	Hyde Griffith	01/22/96
11. Department Manager	Jerry L. Naaf	Jerry L. Naaf	1-23-96

12. REMARKS

1. The following TBVs/ TBDs apply throughout this analysis:
   a. TBV-193-ESF: Seismic design values for steel sets to be verified.
   b. TBD-146-ESF: Thermal design loads for the ESF to be determined.
   c. TBD-147-ESF: Thermally-induced stresses in the steel sets (or lining) to be determined.
   d. TBD-154-RDR: Upgrades (if needed) to linings and ground supports due to a credible explosion & fire will be determined after completion of risk assessment.

Any changes to this analysis as a result of the removal of the above TBVs/TBDs will be carried forward from changes to the ESF Ground Support - Structural Steel Analysis (Ref. 5.1).

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ESF Ground Support - Material Dedication Analysis for Structural Steel and Accessories from a Commercial Grade Source
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4. Revision No.	5. Description of Revision
00	NOTE: The DI for this analysis has been changed to adopt the new CII system. The original DI for this analysis was BABEAB000-01717-0200-00003. Revisions 00, 01, 02, and 03 were developed and approved under the original DI. The new DI is BABEE0000-01717-0200-00004 which is adopted in this analysis. The new DI will start with Revision 00. Section 7.2 of this analysis has been expanded to address the ESF ground support structural steel and accessories material dedication of commercial grade items. BABEE0000-01717-0200-00004 REV 00 Title of analysis changed. Analysis was reformatted to match QAP-3-9, Rev. 06. Commercial Grade definitions expanded to include EPRI Guidelines. General associated changes made throughout. Added Attachment I. Added: TBV-193-ESF, TBD-146-ESF, TBD-147-ESF, and TBD-154-RDR. Initial Issue

1. PURPOSE

The purpose of this analysis is to select the critical characteristics to be verified for steel sets and accessories and the verification methods to be implemented through a material dedication process for the procurement and use of commercial grade structural steel sets and accessories (which have a nuclear safety function) to be used in ground support (with the exception of alcove ground support and alcove opening framing, which are not addressed in this analysis) for the Exploratory Studies Facility (ESF) Topopah Spring (TS) Loop. The ESF TS Loop includes the North Ramp, Main Drift, and South Ramp underground openings.

2. QUALITY ASSURANCE

The quality assurance (QA) classification for items discussed in this analysis is presented in QA Classification Analysis of Ground Support Systems (Reference 5.3). The items analyzed in this document are only the structural steel sets and related accessories used for ESF TS Loop ground support that have been classified: QA-1 and QA-5.

3. METHOD

The analytical method is used in this analysis.

4. DESIGN INPUTS

4.1 DESIGN PARAMETERS

The following design parameters represent minimum material strength characteristics for the items addressed in this analysis (from Reference 5.1). Attachment I to this analysis consists of worksheets that identify all critical characteristics for these items and inspection, testing, and sampling methods necessary to confirm that the item possesses those characteristics. Each of the following items performs a safety related function and require material dedication if purchased as commercial grade items (CGIs):

4.1.1 Structural steel **Shapes** (steel set W-shapes and C-shape lagging) and steel **Plates**: American Society for Testing and Materials (ASTM) A36/A36M carbon steel - 58 kips per square inch (ksi) minimum tensile strength.

4.1.2 Welding **Electrodes**: American Welding Society (AWS) A5.1 E70XX - 70 ksi minimum tensile strength.

4.1.3 Connection **Bolts**: ASTM A307 - 58 ksi minimum tensile strength.

4.1.4 Connection and Tie Rod **Nuts**: ASTM A563 - 175 ksi minimum proof load stress.

4.1.5 **Pipe Spacer**: ASTM A53 carbon steel - 60 ksi minimum tensile strength.

4.1.6 Threaded **Tie Rods**: ASTM A307 carbon steel - 58 ksi minimum tensile strength.

4.1.7 **Connection Shim Plates**: ASTM A36/A36M carbon steel, 58 ksi minimum tensile strength.

4.2 CRITERIA

The following criteria, applicable to ground support structural steel and accessories, were developed in response to requirements found in the Exploratory Studies Facility Design Requirements (ESFDR) document (Reference 5.4).

4.2.1 The structural steel and accessories material and workmanship shall have the same criteria, standards, and QA as required for a repository, to the extent known at the time of structural steel design. (ESFDR 3.2.1.H, H.1, H.1.c)

4.2.2 Structural steel and accessories material and workmanship shall limit adverse effects, to the extent practical, on the long-term performance of the geologic repository and shall not adversely affect in situ site characterization. (ESFDR 3.2.1.M, M.1, M.6)

4.2.3 Special processes for structural steel, including welding and nondestructive testing, shall be controlled and performed by qualified personnel using approved procedures, in accordance with accepted commercial industry standards, as specified in applicable design specifications and drawings. In addition, workmanship criteria shall reflect the applicable current codes, standards, regulations and principles specified in DOE Order 6430.1A, Chapter 0109 (i.e., American Institute of Steel Construction, American Society for Testing and Materials, American Welding Society, and American National Standards Institute, Inc.). (ESFDR 3.2.1.17.A, and B)

4.3 ASSUMPTIONS

Not used.

4.4 CODES AND STANDARDS

4.4.1 American Institute of Steel Construction (AISC):

AISC M016-89	Manual of Steel Construction, Allowable Stress Design, Ninth Edition

4.4.2 American National Standards Institute (ANSI)

ANSI Z1.4-93	Sampling procedures and Tables for Inspection by Attributes

4.4.3 American Society of Mechanical Engineers (ASME):

ASME B18.5-90	Round Head Bolts (Inch Series)

4.4.4 American Society for Testing and Materials (ASTM):

ASTM A6/A6M-94a	Standard Specification for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use
ASTM A36/A36M-94	Standard Specification for Carbon Structural Steel
ASTM A53-94	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A307-94	Standard Specification for Carbon Steel Bolts and Studs 60,000 psi Tensile Strength
ASTM A370-94	Standard Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A563-94	Standard Specification for Carbon and Alloy Steel Nuts
ASTM F436-93	Standard Specification for Hardened Steel Washers
ASTM F606-90	Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

4.4.5 American Welding Society (AWS):

AWS D1.1-94	Structural Welding Code-Steel, 13th Edition
AWS A5.1-91	Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding

4.4.6 Department of Energy (DOE) Orders:

DOE 6430.1A-89	General Design Criteria

4.4.7 Federal Acquisition Regulations (FAR)

FAR 25.1-95	Buy American Act - Supplies
FAR 25.2-95	Buy American Act - Construction Materials

5. REFERENCES

5.1 ESF Ground Support - Structural Steel Analysis, DI: BABEE0000-01717-0200-00003 REV 00.

5.2 *Quality Assurance Requirements and Description* (QARD), U.S. Department of Energy, DOE/RW-0333P Rev. 5.

5.3 QA Classification Analysis of Ground Support Systems (CI: BABEE0000), DI: BABEE0000-01717-2200-00001 REV 02.

5.4 *Exploratory Studies Facility Design Requirements*, YMP/CM-0019 Rev. 1/ICN-3.

5.5 U.S. Nuclear Regulatory Commission (NRC) Generic Letter 91-05, April 9, 1991, "Licensee Commercial-Grade Procurement and Dedication Programs."

5.6 NRC Generic Letter 89-02, March 21, 1989, "Actions to Improve the Detection of Counterfeit and Fraudulently Marketed Products."

5.7 Electric Power Research Institute, (EPRI NP-5652) *Guideline for the Utilization of Commercial Grade Items in Nuclear Safety Related Applications* (NCIG-07), 1988.

5.8 Electric Power Research Institute, (EPRI NP-7218) *Guideline for the Utilization of Sampling plans for Commercial-Grade Item Acceptance* (NCIG-19), 1992.

5.9 Baumeister and Marks, *Standard Handbook for Mechanical Engineers*, Seventh Edition.

6. USE OF COMPUTER SOFTWARE

Not used.

7. DESIGN ANALYSIS

7.1 DEFINITIONS

Following are definitions of selected terms as used in this analysis:

7.1.1 *Critical Characteristic*: Identifiable and measurable attributes/variables of a CGI, which, once selected to be verified, provide reasonable assurance that the item received is the item specified and that the item will perform its intended safety-related function.

7.1.2 *Dedication*: The process by which a CGI is designated for use as a basic component and includes identification and verification of critical characteristics. It also represents the point in time after which a CGI is accepted (dedicated) for a safety-related application and deficiency reporting becomes the responsibility of the party performing the acceptance.

7.1.3 *Commercial Grade Item* (from the QARD, Reference 5.2): An item that is 1) not subject to design or specification criteria that are unique to the Program or nuclear facilities, 2) used in applications other than the nuclear industry, and 3) ordered from the manufacturer or supplier on the basis of specifications set forth in the manufacturer's published product description.

7.1.4 *Certificates of Compliance* (C of Cs): A written statement, signed by an officer of the fabricator/supplier, certifying that the items comply with requirements specified in the procurement documents.

7.1.5 *Certified Material Test Report* (CMTR): A written report identifying tests and test results performed on an item representing a lot (or heat lot) of items and attesting that the test results confirm that those items conform to the requirements of the codes or standards under which the items were manufactured and consistent with the requirements specified in the procurement documents. Report to be certified by an officer of the testing agency.

7.1.6 *Mill Test Reports* (MTRs): MTRs are similar to CMTRs, but may or may not be certified, and report the results of tests performed at the mill by the manufacturer of the basic product. The test results assure that the lot (or heat lot) of items conform to the requirements of the codes or standards under which the items were manufactured and consistent with the requirements specified in the procurement documents.

7.2 BACKGROUND

CGIs intended for use in nuclear safety-related applications are dedicated to ensure that they are acceptable for their intended use. As used in this analysis, the term "safety-related" is synonymous with the project specific term, "Q-listed."

The NRC has published several Generic Letters (References 5.5 and 5.6) that explain its interpretation and position on effective material dedication programs. (The NRC Generic Letters are not ESF program requirements, but cover the topic of concern.) These letters clearly state that procurement is both a purchasing and an engineering function. The engineering function is essential in any material dedication program to identify the critical characteristics of a CGI for the particular design application and to specify acceptance methods necessary to provide assurance that selected critical characteristics are verified for the intended application.

In order to utilize a CGI in a safety-related application, reasonable actions must be taken to assure the item is appropriate for its intended application. As described in Paragraph 7.2.3, below, safety-related items need not be procured from suppliers that maintain a QARD (Reference 5.2) quality assurance program, provided those items meet the CGI definition (Paragraph 7.1.3).

A technical specification for procurement and installation of structural steel and accessories is prepared by the Management and Operating (M&O) Contractor's design organization identifying the technical requirements for the steel materials used in the fabrication of structural steel sets and accessories used for ESF ground support. This steel is not subject to design or specification requirements that are unique to nuclear facilities. Steel sets are used in mine drifts and civil tunnel projects throughout the world. Consequently, such steel sets are used in applications other than nuclear facilities. A commercial grade steel set fabrication source is then presented with the technical specifications and requested to provide detailed shop drawings. The fabricator's standard catalog and detailed shop drawings are or become their published product description. It must be understood that a fabricator of steel sets identifies the items they can fabricate in their standard catalog. A fabricator does not identify a specific steel set they make. They must rely upon the purchaser's design documents for the dimensions required and the commercial materials identification. The fabricator then produces a set of shop drawings that are presented to the purchaser for review and approval.

The purchaser's design organization conducts a technical evaluation of the fabricator's product description to verify that the product to be supplied is appropriate for the intended application. This is a standard commercial practice in the international mining and tunneling industry. Mine drifts and civil tunnels may vary in dimension, but the structural steel sets are typically fabricated of commercially available materials such as ASTM A36/A36M structural steel, E-70XX weld filler material, and ASTM fasteners (bolts, nuts, and washers); and are typically fabricated to commercial fabrication standards (e.g. AWS D1.1 for welding, and AISC M016 for steel fabrication and erection in accordance with Criteria 4.2.3). It is because mine drifts

and civil tunnels vary in opening dimensions and rock or soil loadings that technical specifications identify the tunnel/drift opening dimensions, design structural shape, steel set dimensions, and material types to the fabricator and the fabricator then provides detail drawings of the fabrication for steel sets.

Upon receipt of the fabricator's detail drawings it becomes the designer's responsibility to conduct a technical evaluation of the fabricator's published product description (detail drawings) to verify that the commercial grade steel sets are appropriate for their intended application. This technical evaluation, in combination with the appropriately specified acceptance processes leading to material dedication (further described in this analysis) for the steel sets, provides the assurance that the steel sets are suitable for their intended application, that the items received are the items specified, and that the steel sets can be dedicated as safety-related components after verification of selected critical characteristics by the purchaser.

It is also important to recognize that steel sets installed in the ESF will be accessible. During the life of the steel sets in the ESF, structural loadings at selected locations will be monitored by strain gages. All of the steel sets will be readily observable for inspection purposes. Most will probably not be subjected to their full design loading capability because the sets were designed to unlikely, worst case rock loads which, for the vast majority of steel sets, will never be seen. Consequently, should a limited number of steel sets exhibit an overstress condition, they can be supplemented by additional structural members or removed and replaced should the need arise. For these reasons, dedication of the steel sets as CGIs is considered adequate to ensure that the safety-related function of the steel sets will not be impaired (Criteria 4.2.1).

The M&O addresses the Generic Letter concerns and ESF programmatic requirements by

- Preparing a material dedication analysis (this analysis) to select those critical characteristics to be verified and to identify testing/inspection requirements appropriate to provide reasonable assurance that the items specified are the items received
- Incorporating inspection and testing requirements into the appropriate specification to ensure that the critical characteristics are tested and/or inspected
- Surveillance of inspection and test results to ensure that the critical characteristics are met and properly documented.

7.2.1 NRC Generic Letter GL 91-05, "Licensee Commercial-Grade Procurement and Dedication Programs" (Reference 5.5), explains that certain key activities, including engineering involvement, are required to achieve the successful implementation of licensees' programs for material dedication with respect to critical characteristics. Quoting Reference 5.5:

> The term 'critical characteristics' is not contained in [NRC regulations or guidelines] and has no special regulatory significance beyond its use and definition in various industry guides and standards. The NRC first used the term critical characteristics in NRC GL 89-02 as constituting those characteristics which need to be identified and verified during product acceptance as part of the procurement process.

7.2.2 NRC Generic Letter GL 89-02, "Actions to Improve the Detection of Counterfeit and Fraudulently Marketed Products" (Reference 5.6) states:

> Appropriate engineering involvement is warranted during the procurement and product acceptance processes, including testing, for products used in nuclear power plants. Inadequate engineering involvement has been a common weakness in licensees' procurement programs, particularly when commercial-grade procurements were involved. Involvement of a licensee's engineering staff in an effective procurement process would normally include (1) development of specifications to be used for the procurement of products to be used in the plant, (2) determination of the critical characteristics of the selected products that are to be verified during product acceptance, (3) determination of specific testing requirements applicable to the selected products, and (4) evaluation of test results. The extent of necessary engineering involvement is dependent on the nature and use of the products involved.

7.2.3 A commercial grade source, for the purpose of this analysis, is a supplier who has not been qualified to the requirements of the QARD (Reference 5.2). Items and components for use in safety-related applications need not be procured from suppliers that maintain a quality assurance program which meets the requirements of the QARD, provided that the items meet the CGI definition (Paragraph 7.1.3).

CGIs used in safety-related applications can be shown to be equivalent to a safety-related item purchased as a basic component from a qualified supplier through the implementation of material dedication, provided material dedication is performed in accordance with nuclear industry standards. The Electric Power Research Institute (EPRI) has published a guidance document (Reference 5.7) for dedication of CGIs that is recognized by licensees within the industry as well as by the NRC.

A. Commercial Grade Acceptance Methods: The EPRI NP-5652 (Reference 5.7) guideline states that utilization of a CGI involves two distinct processes: 1) a technical evaluation to assure requirements are specified in the procurement documents, and 2) acceptance methods to reasonably assure the item received is the item specified.

This analysis, combined with the ESF Ground Support - Structural Steel Analysis (Reference 5.1), forms the design basis for the steel set specification. These two analyses constitute the technical evaluation, while the specification provides the vehicle for identifying requirements for procurement.

Regarding acceptance methods, the EPRI guideline (Reference 5.7) identifies four methods which may be used to accept a CGI. These four methods are

- Method 1: Special Tests and Inspections
- Method 2: Commercial Grade Survey of Supplier(s)
- Method 3: Source Verification
- Method 4: Acceptable Supplier/Item Performance Record.

Any of the above methods, or a combination of methods can be used to accept a given CGI. Selection of the appropriate acceptance method or methods to be used is based on factors such as 1) selected critical characteristics, 2) available supplier information, 3) quality history, and 4) degree of standardization.

After a review of the four acceptance methods available, it is determined that Method 2 (Commercial Grade Survey) in combination with a limited version of Method 1 (Special Tests and Inspections) would be most appropriate for acceptance and dedication of the commercial grade structural steel sets, set components, and accessories used in ground support for the ESF.

Method 2, a commercial grade survey of supplier(s), was selected as the primary acceptance method for the following reasons:

- Typically, the steel sets and components are obtained from a single supplier. However, accessories such as nuts, bolts, and washers, may be obtained from many suppliers.

- Normally, large groups of similar items (steel sets) are procured from one supplier.

- The commercial grade item (steel set) is an assembly of many parts.

- Destructive testing and detailed inspections on receipt are time consuming, costly, and these tests/inspections are seldom cost effective.

- All of the materials of the steel set components and accessories are produced to nationally recognized standards (e.g., ASTM).

- The majority of the critical characteristics of the component and accessory items can be related to material characteristics that will be

tested, documented, and certified on material test reports, compliance certifications, or limited receipt inspections and tests.

- Suppliers (fabricators) of structural steel will typically have some system of commercial controls for procurement and fabrication of structural steel assemblies.

- The steel sets and accessories are relatively simple, passive items.

In order to ensure that the items delivered are the specified CGIs, a limited number of special receipt and/or post-installation inspections and tests (Method 1) have been selected to complement the Commercial Grade Survey. These inspections and tests (see Attachment I) will typically consist of non-destructive hardness tests and/or visual inspections on a lot sample of structural steel components at receipt or after installation. For fasteners, however, some minimal destructive testing will be appropriate as the cost for performing Commercial Grade Surveys of the potentially numerous fastener subsuppliers that might be used would be prohibitive. One important aspect of acceptance of the CGIs will be the verification of the acceptability of the C of Cs and related supporting documentation such as Certified Material Test Reports (CMTRs) or Mill Test Reports (MTRs), as appropriate, during the Commercial Grade Survey, and receipt of, as a minimum, the C of Cs for dedication of the related items. Therefore, CGIs for use in the ESF shall be subject to material dedication as prescribed above and in accordance with the following paragraphs.

B. Commercial Grade Survey: Both new and existing commercial grade fabricators/suppliers (and in some cases subsuppliers) shall be subject to a documented Commercial Grade Survey (Method 2 of EPRI NP-5652) to verify that a system of controls are in place to control the fabrication/manufacture of the CGIs, and that these controls are adequate to ensure the items possess the identified critical characteristics. For new procurements, this survey shall be conducted prior to award to either pre-qualify potential suppliers or to disqualify suppliers with inadequate systems for controlling the critical characteristics of the CGIs. Fabricator/supplier controls that should be surveyed include the items as outlined below (from EPRI NP-5652, Exhibit 3):

- *Commercial Quality Program*: Number of QA/QC personnel in relation to total production force; existence and type of quality program documentation; quality program indoctrination and training with regard to handling of CGIs; and management involvement in the quality program.

- *Procurement Document Control:* Do purchase orders (POs) specify technical requirements; are supporting documents (CMTR, MTRs) acceptable and traceable to items received; and who reviews and accepts POs for CGIs?

- *Control of Subsuppliers:* Is there an approved suppliers list (ASL) for CGI subsuppliers; how is a subsupplier added to the list; were subsuppliers evaluated prior to award of contracts; does the system assure only qualified subsuppliers are furnishing CGIs if there is no ASL; are orders for CGIs only issued to qualified subsuppliers or are they issued solely based on price; and is subsupplier documentation reviewed and acceptable?

- *Test and Inspection Controls*: Are receipt inspections performed for CGIs to any procedure; are CGI drawings or other documentation available and used for receipt inspections; what do CGI receipt inspections include; are they documented and maintained; what items have receipt inspections; is there a system to ensure CGIs are inspected against PO requirements; are any critical characteristics tested; are in-process and final inspections conducted to assure product conformance; are testing devices (if used) calibrated to a recognized program; how are deficiencies dispositioned; and who performs the tests and inspections?

- *Material Control and Traceability*: Does the supplier's material control system include a method for marking and identifying CGIs; and are CGIs traceable from their source?

- *Control of Special Processes (Welding)*: Are welders and welding procedures documented and qualified to AWS D1.1 or equivalent standards; is weld filler material controlled and traceable; and are non-destructive examinations performed and documented in accordance with the applicable codes and procurement documents (Criteria 4.2.3)?

- *Control of Handling and Storage:* Are CGIs properly packaged for shipment; are CGIs properly stored and traced from storage through to shipment; who is responsible for CGI packaging and shipment release; and how are non-conforming items handled?

The survey criteria and supplier controls will vary from item to item. A Commercial Grade Survey procedure should be developed, and should include a checklist of items/controls (for each critical characteristic) that will be evaluated at the fabricator's and/or supplier's facilities using EPRI NP-5652 (Ref. 5.7), Exhibit 3 and the above outline as a general guideline. A Commercial Grade Survey of material subsuppliers is also required when

dedication is based on the acceptability of C of Cs, unless the Commercial Grade Survey determines that the fabricator verifies the critical characteristics of materials received from his suppliers and/or subsuppliers. Other than welding controls, the system of fabricator/supplier controls in place need not be formal, documented procedures. However, the survey should 1) confirm that the item's critical characteristics are controlled, and 2) assure that the fabricator's/supplier's activities control the critical characteristics of the CGIs supplied. For undocumented fabricator/supplier controls the Commercial Grade Survey should document the standard procedures used by the fabricator/supplier and an officer of the fabricator/supplier should acknowledge concurrence with the survey's findings.

C. Critical Characteristics: The critical characteristics of Attachment I will be documented on C of Cs for overall compliance, and will typically be supported by detailed test results on CMTRs or MTRs (see Attachment I). The acceptability of these documents will be verified during the Commercial Grade Survey. Should the results of the survey not provide reasonable assurance that the items furnished possess the required critical characteristics, or results in a determination that the fabricator does not have an acceptable Commercial Grade system of controls, additional steps should be taken to provide assurance in the quality of the items furnished. If the fabricator/supplier has no system of controls, this may result in the disqualification of the fabricator and/or suppliers. However, deficiencies identified during the Commercial Grade Survey may be corrected by the fabricator/supplier instituting additional quality controls on the selected critical characteristics or by utilizing any of the other acceptance methods of EPRI NP-5652, subject to review and approval by the A/E. Among the other acceptance methods, special inspections and tests (Method 1) are normally preferred by the A/E.

D. Sample Selection: The sampling methods considered appropriate for dedication of CGIs covered by this analysis are testing and inspection of a statistically significant number of the items. QARD Section 10.2.4 (Reference 5.2) requires that when statistical sampling is used to verify the acceptability of a group of items, the statistical sampling method shall be based on recognized standard practice. For purposes of this analysis, "recognized standard practice" is considered satisfied by development of a sampling plan based upon methods outlined in the EPRI guideline for acceptance of CGIs (Reference 5.8). The approach utilizes a randomly selected statistical sampling population and develops rationale for the selection of an overall sampling plan (see Attachment I).

The selection of a sampling plan should consider applicable selection factors (Reference 5.8) such as lot formation, complexity of items, acceptance history, national standards, performance history, cost effectiveness of tests or

inspections, and correlations between critical characteristics. The EPRI guideline also implies that both qualitative and quantitative historical information from the commercial grade suppliers should be used to aid in establishing the inspection lot size. The guidelines states: "The confidence in the homogeneity of the lot is directly related to how the lot is formed." Therefore, the use of production traceability of lots, such as heat number, production number or batch number; production line item lots from a single product manufacturer; production line item lots from multiple product manufacturers; and multiple production line item lots from single product manufacturers are typically used in establishing lot formation (Reference 5.8).

CGIs shall be subject to acceptance in accordance with a sampling plan developed by the Constructor, approved by the A/E, and based on the randomly selected lot sample acceptance methodology of EPRI NP-7218 to verify the critical characteristics of the material (see Paragraph 7.3.3). For a description of the lot sample methods considered acceptable for each CGI, see Attachment I.

E. Inspection and Testing: Inspection and testing of representative samples shall be performed to verify that the critical characteristics of the CGIs conform to the minimum critical material and dimensional characteristics as determined in Attachment I and summarized in Paragraphs 7.3.2.2.A and B for the purpose of acceptance and dedication. In addition to special tests and inspections, C of Cs (and, in some instances, supporting CMTRs and/or MTRs) shall be furnished for the CGIs. The C of Cs should state that the commercial grade control activities evaluated during the Commercial Grade Survey were invoked in the fabrication/manufacture of the CGI addressed by that C of C. Adequacy and traceability of the C of Cs (including the supporting CMTRs/MTRs) should be established during the Commercial Grade Survey and the C of Cs furnished for dedication of the items. Samples for inspection shall be selected based on Paragraph 7.2.3.D and Attachment I.

F. Buy American: In addition to the above, the M&O procurement documents currently provide that for procurement of supplies and construction materials, preference be given to domestic products (FAR 25.1 and 25.2). In addition, the procurement of certain items (i.e., bolts, nuts, washers) are subject to controls in existing contracts which prevent the use or acquisition of suspect or counterfeit items. This provides additional assurance in the quality of the items received based on the level of quality inherent in U.S. manufactured items of this nature generally recognized throughout the industry.

7.3 STRUCTURAL STEEL GROUND SUPPORT IN ESF

7.3.1 Design Basis

Structural steel ground support in the ESF will consist of steel sets and lagging for the tunnels. The configuration and material properties of steel sets and lagging have been determined by a separate analysis (Reference 5.1).

7.3.2 Descriptions/Functions and Critical Characteristics

7.3.2.1 Component Item Descriptions/Functions

The purpose of the structural steel ground support system, comprised of the steel sets, lagging, tie rods, pipe spacers, connection plates, shims, and accessories, is to maintain a stable, functional opening. Based on a review of Reference 5.1, the basic structural components of the steel set ground support system and a summary of their descriptions/functions are as follows (see Attachment I for more detailed descriptions and an evaluation of critical characteristics and identification of acceptance methods):

A. Steel Sets are curved, wide-flange structural steel beams that act as compression rings to transfer the rock loads onto the precast concrete invert segments.

B. Lagging is a beam element that spans the gap between steel sets to prevent spalling and to distribute the loosening rock load onto the steel set while preventing the loosened rock from falling from between steel sets.

C. Tie rods are threaded steel tension members that connect adjacent steel sets and provide lateral stability during erection and under long-term rock load conditions.

D. Pipe spacers are used to maintain separation of steel sets during erection and to maintain steel set stability and prevent lateral buckling in combination with the tie rods under long-term rock load conditions.

E. Connections of structural steel members include the joint and foot plates and accessories of bolts, nuts, washers (see below), and weld materials. Performance of structural steel components depends upon the developed strength of the connections and therefore the material properties of the joint and foot plates and accessories.

F. Shims are full size flat plates used as filler material or spacers between the inserts and/or the segments of the steel sets or between the pipe spacers and the steel sets. Shims are subject to compression forces and help to maintain the structural continuity of the steel sets.

G. Washers are placed under nuts and/or bolt heads (especially when oversized holes are used) to facilitate tightening of the nuts and/or bolts without galling caused by misalignment or skew of the bolts in the holes. For connections using ASTM A307 bolts, washers are optional at bolted ends and are typically used as a good workmanship practice. Where used, washers shall conform to ASTM F436, Type 1. However, failure of the washers will not result in failure of the connection; therefore, washers do not require material dedication.

7.3.2.2 Structural Steel and Accessories Critical Characteristics

The principal critical design attribute for structural steel and accessories that directly relates to material dedication is the structural capacity of the members which is a function of the material strength and physical dimensions of the structural steel, accessories, and welding materials. Following is a brief summary of the critical characteristics for the items to be dedicated. A detailed determination of the critical characteristics may be found in Attachment I.

A. Critical Characteristics (Material Properties)

The Critical Characteristics of structural steel and accessories have been selected (see Attachment I) and the characteristics are summarized below. These selected critical characteristics as well as other material and physical characteristics necessary to confirm that the items conform to the applicable national code or standard will be documented on C of Cs (and/or supporting CMTRs/MTRs as appropriate). For any of these items, material of equal or greater strength may be substituted subject to A/E approval.

1. Structural steel shapes and plates: ASTM A36/A36M carbon steel - 58 ksi minimum tensile strength.

2. Welding electrodes: AWS A5.1, E70XX, 70 ksi minimum tensile strength.

3. Bolted steel set connections:

- ASTM A307 bolts, 58 ksi minimum tensile strength
- ASTM A563 nuts, heavy hex, Grade DH 175 ksi proof load stress

4. Tie rods: ASTM A307, carbon steel, 58 ksi minimum tensile strength. For tie rod nuts, see item 3, above.

5. Pipe spacers: ASTM A53 Grade B carbon steel pipe, 60 ksi minimum tensile strength.

B. Critical Characteristics (Dimensional)

The physical dimensions of the structural steel and certain accessories identified above are critical to the performance of these items and shall comply with the A/E approved shop drawings and the following:

1. Structural steel shapes and plates: ASTM A6/A6M
2. Bolts: ASTM A307, Section 7.0
3. Nuts: ASTM A563, Section 7.0
4. Tie Rods: ASTM A307, Section 7.0
5. Pipe spacers: ASTM A53, Sections 15, 16, and Table X2.2.

It should be noted that some of the dimensional tolerances identified in Attachment VII of Reference 5.1 may differ from those national standards shown above. In case of conflict, the relaxed tolerances in Reference 5.1 shall govern.

7.3.3 Sampling Method

The sampling method considered appropriate for receipt inspection and testing of steel materials is the lot sample acceptance methodology based on the guidelines contained in EPRI NP-7218, Table 2-1. A sampling plan that conforms to the EPRI NP-7218 generic guidelines and the more detailed sampling requirements on the worksheets of Attachment I should be developed by the Constructor to address receipt inspection and testing of items and welds. The Constructor shall submit this sampling plan to the A/E for review and approval.

7.3.3.1 Inspection/Testing Criteria for Items to be Dedicated

A. Receipt Inspection/Testing by Constructor

Documented receipt inspection and testing of a lot sample of items classified QA-1 and QA-5 that are purchased from a Commercial Grade source shall include (also see Attachment I):

1. Dimensional/visual inspection for conformance with purchasing documents (shop drawings and specification).

2. Assurance that certification documents (C of Cs) required by the purchasing documents are received, acceptable, and consistent with the results of the Commercial Grade Survey.

3. Inspection to ensure that damage was not sustained during shipping.

4. Assurance that the items received are the items identified on the purchasing documents and accompanying C of Cs.

5. Inspection of welds on a sample of items in accordance with Attachment I (Criteria 4.2.3).

6. Mechanical testing of structural steel shapes, joint and foot plates, pipe, and tie rods shall consist of hardness testing, which can be used to obtain a quick approximation of tensile strength, in accordance with the methods described in ASTM A370, Sections 15 through 18 as follows:

    - For ASTM A36/A36M carbon steel materials, Brinell hardness shall be a minimum of 119 (corresponds to approximate tensile strength of 58 ksi).

    - For materials other than ASTM A36/A36M steels, Brinell hardness shall be derived from ASTM A370, Table 2B corresponding to the approximate minimum tensile strength for the material from the applicable ASTM Standard for that material.

    - Hardness scales other than the Brinell scale may be used by utilizing ASTM A370, Table 2B to convert the Brinell hardness numbers to the other scale.

    - In addition to hardness testing, a magnet test will be used to confirm the presence of iron.

The use of hardness testing in combination with magnet testing is currently being used in the commercial nuclear industry as a means of assessing the relative mechanical strength of carbon steel products. As noted in ASTM A370, Section 15 and in the Mechanical Engineer Handbook, Chapter 5 (Reference 5.9, pp. 5-15 to 5-17), hardness is a composite mechanical property that includes yield strength, work hardening, true tensile strength, modulus of elasticity, and others. Due to the empirical relationships of hardness to such properties as tensile strength, ductility, and fatigue strength, items likely to be deficient may be detected and rejected by confirmation of the hardness value.

7. Mechanical testing of bolts and nuts shall be in accordance with ASTM F606. See Attachment I for specific testing requirements.

8. Visual confirmation that the bend radius of the steel sets is reasonably uniform (i.e., does not have visibly noticeable abrupt upsets or inflections).

9. Assurance that the tie rod hole spacing conforms to requirements.

B. Material Control by Constructor

In addition to the receipt and post installation inspection requirements above, the following controls are needed to ensure the integrity of the dedicated CGIs after receipt and prior to installation:

1. Ensure that storage of materials is in accordance with manufacturer's recommendations or approved Constructor storage requirements.

2. Ensure that materials received are controlled to preclude inadvertent use of items prior to receipt acceptance.

3. Ensure materials that are purchased and accepted for use in safety-related applications are identified to distinguish them from those like items purchased and accepted for use in non-safety-related applications.

4. Ensure materials that are purchased and accepted for use in safety-related applications are segregated from those like items purchased and accepted for use in non-safety-related applications.

C. Post Installation Dedication Inspection by Constructor

Prior to completing dedication of completed steel set assemblies, visual confirmation that the steel set assembly is able to be installed on the concrete invert segment curb, that it makes positive contact with the rock to the extent practical, and that the set spacing conforms to requirements shall be performed and documented after the jacking/expansion process is complete. This will confirm the adequacy of the steel set bend radius, and tie rod/pipe brace length dimensions.

8. CONCLUSIONS

The information in Section 7 and Attachment I provides the necessary architect/engineer design inputs for providing material dedication requirements in the specification section for structural steel and accessories used in ground support for the ESF TS Loop. In addition, the criteria identified in Paragraph 4.2 have been incorporated generally throughout this analysis and specifically where noted.

9. ATTACHMENTS

ATTACHMENT	TITLE
I	Commercial Grade Item (CGI) Critical Characteristics Identification Worksheets.

COMMERCIAL GRADE ITEM (CGI) CRITICAL CHARACTERISTICS IDENTIFICATION WORKSHEETS

The following worksheets provide the rationale for the selection of critical characteristics for the safety-related commercial grade items (CGI) as identified in the body of this analysis, and verification methods for those characteristics based on the guidelines in EPRI NP-5652 (Reference 5.7) and EPRI NP-7218 (Reference 5.8). Selection of Normal or Reduced sampling methods is based on the relative importance of each item to the overall performance of the ground support system (e.g., steel sets and lagging), and on a review of lots of steel set and accessory items and associated C of Cs, CMTRs and/or MTRs delivered to date. The Tightened sampling method is not considered appropriate since the Commercial Grade (CG) Survey will provide a reasonable degree of assurance in the quality of items delivered, and only limited receipt inspection, testing, and verification is needed. For items of lesser relative importance to the performance of the steel set system (e.g., shims, plates, and accessories), the Reduced sampling method is considered appropriate throughout the receipt acceptance process.

For structural steel members, a hardness test and a magnet test can be used to verify with reasonable assurance that selected steel items are acceptable, or can be used to detect deficiencies and as a means to reject items. The magnet test will verify that the item contains iron. The results of the CG Survey, receipt of acceptable C of Cs (typically supported by CMTRs and/or MTRs) in conjunction with a hardness test (correlated to tensile strength using ASTM A370, Table 2B) and a magnet test, provides reasonable assurance that the minimum tensile strength attribute is present. It is important to note that these tests will not provide exact quantitative evidence of the tensile strength or that the items are made of carbon steel. However, once the hardness attributes in combination with the presence of iron are verified, together with the CG Survey and receipt of acceptable documentation, one can be reasonably assured that the item will perform its safety- related function.

The frequency of testing on lot samples at receipt necessary to represent material hardness considered appropriate is an average of 3 tests in accordance with the hardness verification and calibration testing recommendation of from 3 to 5 tests cited in ASTM A370 and related hardness testing standards. The post-installation inspection frequency for the steel sets will be addressed in the Constructor's Sampling Plan which will be approved by the A/E.

The methods for randomly selecting samples for inspection and testing, and for formation of lots shall be developed by the Constructor, and documented in the A/E approved Sampling Plan , using EPRI NP-7218, Paragraphs 1.3.3 and 2.3, respectively (including associated references, i.e., ANSI Z1.4) as guidance. This Sampling Plan will be submitted to the A/E for approval. Where accessibility of an item for inspection becomes an issue (i.e., connection plate welds since the segments are delivered in stacks making many of the plates inaccessible for visual inspection of these welds), the randomly selected samples may be limited to only those items readily accessible for inspection. The Constructor's sampling method and rationale for relaxing or increasing the sampling frequency shall be based on either a number of consecutively acceptable samples or on a number of consecutively acceptable lots, and shall be addressed in the Sampling Plan.

Supporting CMTRs/MTRs will be submitted for information and record only. However, these documents are not intended to be used for heat lot traceability to individual items, but only for purposes of providing tensile strength and other mechanical and/or chemical properties representative of the aggregate of items used to fill a particular purchase order.

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Steel Set Assembly
Part/Item: Steel Set W-Shape Segments (Including Inserts)

1. *What is the Function of the Item and how could it fail in service?*

   The W-shape steel set, which consists of wall, crown, insert, and foot segments, carries the long term rock loads (including utility and seismic loads) primarily in ring compression and transfers those loads into the precast concrete invert segments. These primary components maintain a stable, functional tunnel opening when using steel sets for ground support. The W-shape steel set segments could fail in compression (buckling), bending, or shear. Failure of the individual segments of the steel set could also result in failure of the overall steel set. Therefore, since the segments are critical to the performance of the overall steel set, normal sampling methods are considered appropriate.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
   - N/A

   B. *Physical Attributes:*
   - Minimum tensile strength 58 ksi
   - W-Shapes shall be made of carbon steel
   - Dimensions comply with specification requirements (as derived from Ref 5.1)
   - Radius is uniform and accommodates nominal tunnel diameter
   - Spacing of tie rod holes comply with specification requirements (as derived from Ref 5.1)

   C. *Performance Characteristics:*
   - Makes positive contact with tunnel wall, to the extent practical
   - Properly founded on invert segment curb
   - Spaced at nominal 2, 4, or 6 ft based on rock conditions encountered

3. *How will the critical characteristics of item 2, above be verified?*

   A. Minimum tensile strength will be verified based on the results of the Commercial Grade (CG) Survey, receipt of acceptable C of Cs, and hardness tests on lot samples.

   B. Assurance that shapes are made of carbon steel will be verified by a magnet test in combination with receipt of acceptable C of Cs.

C. Verification that the steel set segment radius, dimensions, and tie rod hole spacing comply with specification requirements will be based on the results of the CG Survey, receipt of acceptable C of Cs, and lot sample inspection/measurement of the following: 1) the radius of the steel set segments (verified by visually confirming uniformity at receipt), 2) tie rod hole spacing and location, and 3) W-shape dimensions (see below).

D. For the verification of the performance characteristics of item 2.c, above, see item 4.b, below.

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

A. In addition to the normal receipt inspection of Paragraph 7.3.3.1A, randomly selected lot samples for inspection of dimensions, a magnet test, and a hardness test shall be performed. The magnet test will verify the presence of iron. Hardness value will be the average of **3** tests at random locations on each segment sampled, to be used as a basis for rejection of an item or lot as non-conforming. Beam dimensions (**depth, flange width and flange thickness**) will be measured at a minimum of **one** random location to confirm W-shape size. Uniformity of bend radius will be confirmed by visually verifying that the curved segments do not have noticeably abrupt upsets or inflections. Tie rod hole spacing and location will also be measured at receipt. Overall segment dimensions and bend radius need not be measured on receipt as these characteristics will be verified by successful installation. Because the segments are critical to the performance of the steel set assembly, the inspection/test population shall be based on the **Normal** Sampling Plan of EPRI NP-7218, Table 2-1. Once a successful history of consecutively acceptable lots or samples (based on the Constructor's A/E approved Sampling Plan) has been established, the sampling may be changed to the **Reduced** Sampling Plan of Table 2-1. Defects may be cause for rejection of a lot, and will result in increased sampling frequencies on that lot (if not rejected), and on subsequent lots until satisfactory evidence of a history of successful results are again achieved (to be addressed in Constructor's A/E approved Sampling Plan).

B. Post installation inspection of the assembled steel sets (Paragraph 2.c, above) shall be performed and shall consist of: 1) visually confirming that the set can be installed, 2) verifying that positive contact with the tunnel rock wall is achieved to the extent practical, 3) visually confirming and/or measuring steel set spacing to assure spacing tolerances are met, and 4) visually confirming and/or measuring proper base plate location on the curb of the concrete invert.

C. Dedication of the overall steel set assembly and steel set segments (including base/connection plates) will not occur until after completion of the above post-installation inspections; but the individual ESF ground support components (lagging assemblies, tie rods, pipe bracing, and other safety-related accessories) will be dedicated upon completion of receipt inspection and testing.

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Steel Set Assembly
Part/Item: Foot Plates and Joint Plates

1. *What is the Function of the Item and how could it fail in service?*

   The foot plates spread the steel set load onto the precast concrete invert segments in bearing on the concrete. The joint plates join the segments of the steel set together so they will function as a unit, and transfer the load in one segment into the other segment through compression bearing. The foot and joint plates could fail in compression. In addition, the foot plates could fail in bending, could fail in sliding, or could cause localized bearing or shear failure in the curb of the concrete invert. Failure of these plates could also result in failure of the overall steel set. However, failure of the joint and foot plates is considered unlikely as the loads which would cause failure are well in excess of anticipated load conditions. In addition, the compression area on the W-shape is many times smaller than the joint plates, and would fail in compression buckling long before the joint plates would. Therefore, a reduced sampling plan is considered appropriate for the joint and foot plates.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
      - N/A

   B. *Physical Attributes:*
      - Minimum tensile strength 58 ksi
      - Joint and foot plates shall be made of carbon steel
      - Dimensions comply with specification requirements (as derived from Ref 5.1)

   C. *Performance Characteristics:*
      - N/A

3. *How will the critical characteristics of item 2, above be verified?*

   A. Minimum tensile strength will be verified based on the results of the CG Survey, receipt of acceptable C of Cs, and hardness tests on lot samples.

   B. Assurance that the plates are made of carbon steel will be verified by a magnet test in combination with receipt of acceptable C of Cs.

C. Verification that the plate dimensions comply with specification requirements will be based on the results of the CG Survey, receipt of acceptable C of Cs, and lot sample receipt inspection/measurement of dimensions.

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

In addition to the normal receipt inspection of Paragraph 7.3.3.1A, randomly selected lot samples for inspection of critical dimensions (**thickness and plan dimensions**), a magnet test, and a hardness test on segment foot and joint plates shall be performed. The magnet test will verify the presence of iron. Hardness value will be the average of **3** tests at random locations on each plate sampled, to be used as a basis for rejection of an item or lot as non-conforming. Note that each steel set segment will be furnished with two joint plates - one at each end. Because it is unlikely that failure of these plates could occur, the foot/joint plate inspection population shall be based on the **Reduced** Sampling Plan of EPRI NP-7218, Table 2-1. Plates sampled may be the plates on the segments selected for receipt inspection. Only one plate on each segment sample selected need be inspected. Defects may be cause for rejection of a lot, and will result in increased sampling frequencies on that lot (if not rejected) and on subsequent lots until satisfactory evidence of a history of successful results are again achieved (to be addressed in Constructor's A/E approved Sampling Plan).

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Steel Set Assembly
Part/Item: Shim Plates

1. *What is the Function of the Item and how could it fail in service?*

   The shim plates act as spacers in the joints between the steel set segments (or insert segment) and act in compression bearing. Like the connection plates, the shim plates transfer the load in one segment into the other segment through compression bearing. The shim plates could theoretically fail in compression or could slide out of the joint if loaded laterally. However, failure of the shim plates is considered unlikely as the loads which would cause failure are well in excess of anticipated load conditions. In addition, the compression area on the W-shape is many times smaller than the shim plates, and would fail in compression buckling long before the shim plates would. Therefore, since failure of the shim plates is unlikely, reduced sampling methods will apply, and hardness testing to verify tensile strength is not required.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
      - N/A

   B. *Physical Attributes:*
      - Minimum tensile strength 58 ksi
      - Shim plates shall be made of carbon steel
      - Dimensions comply with specification requirements (derived from Ref 5.1)

   C. *Performance Characteristics:*
      - N/A

3. *How will the critical characteristics of item 2, above be verified?*

   A. Minimum tensile strength will be verified based on the results of the CG Survey, and receipt of acceptable Certificates of Compliance (C of Cs).

   B. Assurance that the shims were made of carbon steel will be verified by a magnet test in combination with receipt of acceptable C of Cs.

   C. Verification that the shim plate dimensions comply with specification requirements will be based on the results of the CG Survey, receipt of acceptable C of Cs, and minimal lot sample receipt inspection/measurement of dimensions.

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

In addition to the normal receipt inspection of Paragraph 7.3.3.1A, randomly selected lot samples for inspection of critical dimensions (**thickness and plan dimensions**) and a magnet test on shim plates shall be performed. The magnet test will verify the presence of iron. For each shim plate thickness, because failure of the shim plates is unlikely, the shim plate inspection population shall be based on the **Reduced** Sampling Plan of EPRI NP-7218, Table 2-1. Defects may be cause for rejection of a lot, and will result in increased sampling frequencies on that lot (if not rejected) and on subsequent lots until satisfactory evidence of a history of successful results are again achieved (to be addressed in Constructor's A/E approved Sampling Plan).

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Steel Set Assembly
Part/Item: Connection Sub-assembly (**Bolts**, Nuts, Washers and Welds)

1. *What is the Function of the Item and how could it fail in service?*

   The connection bolts, along with the nuts, washers and welds act to join the segments of the steel set together so they will function as a unit, and transfers the load in one segment into the other segment through shear alone, or in shear and tension (if bending is present). The connection bolts could fail in shear and/or tension. Failure of the bolts could also result in failure of the overall steel set; however, by design, the bolts are only loaded to a fraction (approximately 1/3) of their design capacity under worst case rock and seismic load conditions. Therefore, since the bolts are lightly loaded and failure is unlikely, reduced sampling methods will apply. However, limited tensile testing will be used in lieu of a CG Survey of the bolt subsuppliers.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
      - ASTM A307 Head Markings

   B. *Physical Attributes:*
      - Minimum tensile strength 58 ksi
      - Dimensions comply with specification requirements (as derived from Ref 5.1)

   C. *Performance Characteristics:*
      - N/A

3. *How will the critical characteristics of item 2, above be verified?*

   A. Minimum tensile strength will be verified based on limited tensile testing in lieu of a CG Survey of subsuppliers (C of Cs are optional).

   B. Verification that the bolt head dimensions, bolt diameter and grade marking comply with specification requirements will be based on lot sample receipt inspection/measurement of dimensions and visual verification of head markings.

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

   In addition to the normal receipt inspection of Paragraph 7.3.3.1A, randomly selected lot samples for inspection of critical dimensions (**diameter**) and head markings on connection

bolts shall be performed. For each bolt size, because the bolts are lightly loaded, the bolt inspection population shall be based on the **Reduced** Sampling Plan of EPRI NP-7218, Table 2-1. Randomly selected samples shall be tested for tensile strength in accordance with ASTM F606, Section 3. As a minimum, the number of samples tested for tensile strength shall be in accordance with ASTM A307, Paragraph 8.4. Defects may be cause for rejection of a lot, and will result in increased sampling frequencies on that lot (if not rejected) and on subsequent lots until satisfactory evidence of a history of successful results are again achieved (to be addressed in Constructor's A/E approved Sampling Plan).

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Steel Set Assembly
Part/Item: Connection Sub-assembly (Bolts, **Nuts**, Washers and Welds)

1. *What is the Function of the Item and how could it fail in service?*

   The connection nuts, along with the bolts, washers and welds act to join the segments of the steel set together so they will function as a unit by tensioning the bolts and compressing the connection plates together. The connection nuts could fail in tension (proof load). However, the tension load in the bolt/nut is well below the design capacity of the nut. Failure of the nuts, under certain unlikely conditions, might result in failure of the bolts in the connecting joint thus resulting in possible failure of the overall steel set. Therefore, since the nuts are lightly loaded in tension, and failure is unlikely, reduced sampling methods will apply. However, limited proof load testing will be used in lieu of a CG Survey of the nut subsuppliers.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
   - ASTM A563, Heavy Hex, Grade DH marking on one face

   B. *Physical Attributes:*
   - Minimum proof load stress 175 ksi
   - Dimensions comply with specification requirements (as derived from Ref 5.1)

   C. *Performance Characteristics:*
   - N/A

3. *How will the critical characteristics of item 2, above be verified?*

   A. Minimum proof load stress will be verified based on limited proof load testing in lieu of a CG survey of subsuppliers (C of Cs are optional).

   B. Verification that the nut dimensions and grade marking comply with specification requirements will be based on lot sample receipt inspection/measurement of dimensions and verification of grade markings.

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

   In addition to the normal receipt inspection of Paragraph 7.3.3.1A, randomly selected lot samples for inspection of critical dimensions (**diameter and thickness**) and grade marking

on connection nuts shall be performed. For each nut size, because the nuts are lightly loaded and failure is unlikely, the nut inspection population shall be based on the **Reduced** Sampling Plan of EPRI NP-7218, Table 2-1. Randomly selected samples shall be tested for proof load stress in accordance with ASTM F606, Section 4. As a minimum, the number of samples tested for proof load stress shall be in accordance with ASTM A563, Paragraph 9.3. Defects may be cause for rejection of a lot, and will result in increased sampling frequencies on that lot (if not rejected) and on subsequent lots until satisfactory evidence of a history of successful results are again achieved (to be addressed in Constructor's A/E approved Sampling Plan).

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Steel Set Assembly
Part/Item: Connection Sub-assembly (Bolts, Nuts, **Washers** and Welds)

1. *What is the Function of the Item and how could it fail in service?*

   The connection washers, along with the bolts, nuts and welds act to join the segments of the steel set together so they will function as a unit. The washers, typically used at oversized holes in the connecting plates and where high strength bolts are used, facilitate tightening of the nuts and/or bolts without causing galling in the connected parts due to misalignment or skew of the bolts in the bolt holes. For connections using ASTM A307 bolts, washers are optional at bolted ends. If used, the connection washers could fail in compression bearing. However, failure of a washer would not result in progressive failure of the nut, bolt, or connection. Primarily, the washer is used as a good workmanship practice in accordance with the AISC M016. Therefore, since failure of the washers is unlikely and will not result in failure of the connection, washers are not critical to the performance of the connection and material dedication is not required.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
   - N/A

   B. *Physical Attributes:*
   - N/A

   C. *Performance Characteristics:*
   - N/A

3. *How will the critical characteristics of item 2, above be verified?*

   N/A

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

   N/A

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Steel Set Assembly
Part/Item: Connection Sub-assembly (Bolts, Nuts, Washers and **Welds**)

1. *What is the Function of the Item and how could it fail in service?*

   The connection welds, along with the bolts, nuts and washers act to join the segments of the steel set together so they will function as a unit by connecting the W-shapes to the connection plates. The welds attaching the W-shape webs to the connection/base plates are the primary shear resisting welds in the connection. The connection welds could fail in tension (direct or due to bending) or shear. Failure of the welds, under certain conditions, might result in failure of the connecting joint thus resulting in possible failure of the overall steel set. However, the welds provided are relatively lightly loaded in shear, have a capacity over 10 times that of the demand load, and primarily provide continuity between the steel set W-shape and the connection plates. Therefore, since the welds are lightly loaded in shear, and failure is unlikely, reduced sampling methods will apply.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
   - N/A

   B. *Physical Attributes:*
   - Minimum tensile strength 70 ksi
   - Dimensions comply with specification requirements (as derived from Ref 5.1)
   - Weld quality complies with AWS D1.1 criteria
   - Weldability of the base metal (carbon content)

   C. *Performance Characteristics:*
   - N/A

3. *How will the critical characteristics of item 2, above be verified?*

   A. Minimum tensile strength will be verified based on the results of the CG Survey and receipt of acceptable C of Cs for the electrodes.

   B. Verification that the weld dimensions comply with specification requirements will be based on the results of the CG Survey, and lot sample receipt visual inspection by certified weld inspectors on 100% of the welds included in the sample using the acceptance criteria of AWS D1.1, Sections 6 and 9.25.1 (except 1/32 inch deep undercut criteria applies to all welds).

C. Verification that weld quality complies with AWS M016 requirements will be based on the results of the CG Survey, and visual inspection at receipt as noted in subparagraph 3.b, above.

D. Weldability of the base metal will be verified based on the receipt of acceptable C of Cs for the shapes or plates (see Worksheets for steel set W-shape segments and foot/connection plates) which will assure conformance with ASTM A36/A36M. If the materials conform to ASTM A36/A36M, the chemical composition (carbon content) of these materials (as confirmed on the C of Cs and related supporting documentation) will be within acceptable limits.

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

In addition to the normal receipt inspection of Paragraph 7.3.3.1A, visual inspection of 100% of the welds shall be performed on a lot sample of randomly selected steel set segment connection plate welds that are reasonably accessible for inspection. The number of segments to be have welds visually inspected shall be based on the **Reduced** Sampling Plan of EPRI NP-7218, Table 2-1. Welds sampled may be the readily accessible welds on the steel set segments selected for receipt inspection (see preceding Worksheet for steel set segments). Defects may be cause for rejection of a lot, and will result in increased sampling frequencies on that lot (if not rejected) and on subsequent lots until satisfactory evidence of a history of successful results are again achieved (to be addressed in Constructor's A/E approved Sampling Plan).

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Lagging Assembly
Part/Item: Channel Lagging Beam

1. *What is the Function of the Item and how could it fail in service?*

   The channel lagging beams carry the long term rock loads (including seismic loads) in shear and bending and transfer those loads into the steel set ring beam. This maintains a stable, functional tunnel opening. The channel lagging beam could fail in bending or shear. Failure of the lagging beams could result in localized rock falls, but would not result in the failure of the steel set assembly thereby facilitating repair/replacement of the lagging. Therefore, reduced sampling methods are considered appropriate.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
   - N/A

   B. *Physical Attributes:*
   - Minimum tensile strength 58 ksi
   - Lagging beams shall be made of carbon steel
   - Dimensions comply with specification requirements (as derived from Ref 5.1)

   C. *Performance Characteristics:*
   - N/A

3. *How will the critical characteristics of item 2, above be verified?*

   A. Minimum tensile strength will be verified based on the results of the CG Survey, receipt of acceptable C of Cs, and magnet and hardness tests on lot samples.

   B. Assurance that lagging beams are made of carbon steel will be verified by a magnet test in combination with receipt of acceptable C of Cs.

   C. Verification that the lagging beam dimensions comply with specification requirements will be based on the results of the CG Survey, receipt of acceptable C of Cs, and lot sample receipt inspection/measurement of dimensions.

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

In addition to the normal receipt inspection of Paragraph 7.3.3.1A, randomly selected lot samples for inspection of dimensions, a magnet test, and a hardness test shall be performed. The magnet test will verify the presence of iron. Hardness value used will be the average of **3** tests at random locations on each nominal 2 ft or 4 ft length of C-shape beam sampled and will only be used as a basis for rejection of an item. C-shape lagging beam critical cross-sectional dimensions will be measured at a minimum of **one** location on each lagging beam sampled. Because failure of this item will not result in failure of the steel sets, the test population shall be based on the **Reduced** Sampling Plan of EPRI NP-7218, Table 2-1. Defects may be cause for rejection of a lot, and will result in increased sampling frequencies on that lot (if not rejected) and on subsequent lots until satisfactory evidence of a history of successful results are again achieved (to be addressed in Constructor's A/E approved Sampling Plan).

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Lagging Assembly
Part/Item: Lagging Clamps and Accessories (Carriage Bolts, Nuts and Washers)

1. *What is the Function of the Item and how could it fail in service?*

   This analysis does not address the purchase of commercial grade safety-related lagging clamps based on the fact that the project no longer uses that style of clamp (friction-type) on the lagging beams. They have been replaced by a non-safety-related clamp which bears directly on the top of the steel set wide flange ring beam. Failure of this type of clamp (bearing-type) would not result in failure of the lagging beam as the rock loads are transferred directly in bearing. In addition, the bolts, nuts and washers used in conjunction with the lagging clamp are primarily erection aids and are not critical to the performance of the lagging beam. Therefore, since failure of the bearing-type of clamps and accessories will not result in failure of the lagging beam, material dedication of these items is not required.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
   - N/A

   B. *Physical Attributes:*
   - N/A

   C. *Performance Characteristics:*
   - N/A

3. *How will the critical characteristics of item 2, above be verified?*

   N/A

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

   N/A

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Tie Rod Assembly
Part/Item: Tie Rod

1. *What is the Function of the Item and how could it fail in service?*

   The tie rod acts in tension to laterally brace the steel sets during erection and against compression buckling and weak axis column buckling under long term rock loads by limiting the unbraced length of the steel set ring beam in weak axis bending. The tie rod could fail in tension, and failure of the tie rod could also result in failure of the overall tie rod assembly, possibly resulting in buckling of the steel set. Therefore, since the tie rods are critical to the performance of the tie rod and steel set assemblies, normal sampling methods will apply.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
   - N/A

   B. *Physical Attributes:*
   - Minimum tensile strength 58 ksi
   - Tie Rods shall be made of carbon steel
   - Dimensions comply with specification requirements (as derived from Ref 5.1)

   C. *Performance Characteristics:*
   - N/A

3. *How will the critical characteristics of item 2, above be verified?*

   A. Minimum tensile strength will be verified based on the results of the CG Survey and receipt of acceptable C of Cs, and magnet and hardness tests on lot samples. As an alternative to this approach, tensile testing of the tie rod (with or without the nut attached) will be allowed.

   B. Assurance that the tie rods are made of carbon steel will be verified by use of a magnet test in combination with receipt of acceptable C of Cs (optional - C of Cs required only if tensile testing is not conducted).

   C. Verification that the tie rod dimensions comply with specification requirements will be based on lot sample receipt inspection/measurement of dimensions.

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

In addition to the normal receipt inspection of Paragraph 7.3.3.1A, randomly selected lot samples for inspection of dimensions (**diameter**), a magnet test, and a hardness test on tie rods shall be performed. The magnet test will verify the presence of iron. Hardness value used will be the average of **3** tests at random locations on each nominal 2 ft or 4 ft length of tie rod sampled and will only be used as a basis for rejection of an item. As an alternative to hardness and magnet testing, randomly selected tie rod (or tie rod plus nut) samples may be tested for tensile strength in accordance with ASTM F606, Section 3. As a minimum, the number of samples tested for tensile strength (if used) shall be in accordance with ASTM A307, Paragraph 8.4. Because this item is critical to the performance (stability) of the steel set assembly, the tie rod inspection/test population shall be based on the **Normal** Sampling Plan of EPRI NP-7218, Table 2-1. Once a successful history of consecutively acceptable lots or samples , based on the Constructor's A/E approved Sampling Plan, has been established, the sampling lot size may be changed to the **Reduced** Sampling Plan of Table 2-1. Defects may be cause for rejection of a lot, and will result in increased sampling frequencies on that lot (if not rejected) and on subsequent lots until satisfactory evidence of a history of successful results are again achieved (to be addressed in Constructor's A/E approved Sampling Plan).

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Tie Rod Assembly
Part/Item: Tie Rod Nut

1. *What is the Function of the Item and how could it fail in service?*

   The tie rod nut resists a tension load on the tie rod from the steel sets. The tie rod nut could fail under the tension load in the tie rod. However, this tension load is well below the design capacity of the nut. Failure of the tie rod nut, though unlikely, could result in failure of the overall tie rod and tie rod assembly, possibly resulting in buckling of the steel set. Therefore, since the tie rod nut is lightly loaded, and failure is unlikely, reduced sampling methods will apply.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
   - ASTM A563 grade marking on one face

   B. *Physical Attributes:*
   - Minimum proof load stress 175 ksi
   - Dimensions comply with specification requirements (as derived from Ref 5.1)

   C. *Performance Characteristics:*
   - N/A

3. *How will the critical characteristics of item 2, above be verified?*

   A. Minimum proof load stress will be verified based on limited proof load testing in lieu of a CG Survey of subsuppliers (C of Cs are optional).

   B. Verification that the nut dimensions and grade marking comply with specification requirements will be based on lot sample receipt inspection/measurement of dimensions and verification of grade markings.

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

   In addition to the normal receipt inspection of Paragraph 7.3.3.1A, randomly selected lot samples for inspection of critical dimensions (**diameter and thickness**) and grade markings on tie rod nuts shall be performed. Because this item is loaded well below its proof load capacity, the nut inspection population shall be based on the **Reduced** Sampling Plan of EPRI NP-7218, Table 2-1. Randomly selected samples based on lot sizes delivered will be tested

for proof load stress in accordance with ASTM F606, Section 4. As a minimum, the number of samples tested for proof load stress shall be in accordance with ASTM A563, Paragraph 9.3. If the tie rod nuts are tension tested in combination with the tie rods (see previous Worksheet), the requirement for proof load testing is waived. Defects may be cause for rejection of a lot, and will result in increased sampling frequencies on that lot (if not rejected) and on subsequent lots until satisfactory evidence of a history of successful results are again achieved (to be addressed in Constructor's A/E approved Sampling Plan).

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Tie Rod Assembly
Part/Item: Pipe Brace

1. *What is the Function of the Item and how could it fail in service?*

   The pipe brace acts in compression to laterally brace the steel sets against compression buckling and limit the unbraced length of the steel set ring beam in weak axis bending. The pipe brace is needed because the tie rod is not effective in compression. The pipe brace could fail (buckle) in compression. However, the pipe brace is typically not loaded by action (deflection) of the steel sets, but by the tensioning of the tie rod - a load only about ½ of the capacity of the brace. Failure of the pipe brace (primarily on the first and last steel sets in series of steel sets) could potentially result in failure of the overall tie rod assembly. Although unlikely, this could possibly result in buckling of the steel set. Therefore, since failure of the pipe braces would, more than likely, not result in failure of the steel set assemblies, reduced sampling methods are considered appropriate.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
      - N/A

   B. *Physical Attributes:*
      - Minimum tensile strength 60 ksi
      - Pipe Braces shall be made of carbon steel
      - Dimensions comply with specification requirements (as derived from Ref 5.1)

   C. *Performance Characteristics:*
      - N/A

3. *How will the critical characteristics of item 2, above be verified?*

   A. Minimum tensile strength will be verified based on the results of the CG Survey, receipt of acceptable C of Cs, and magnet and hardness test on lot samples.

   B. Assurance that the pipe braces are made of carbon steel will be verified by use of a magnet test in combination with receipt of acceptable C of Cs.

   C. Verification that the pipe brace dimensions comply with specification requirements will be based on the results of the CG Survey, receipt of acceptable C of Cs, and lot sample receipt inspection/measurement of dimensions.

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

In addition to the normal receipt inspection of Paragraph 7.3.3.1A, randomly selected lot samples for inspection of critical dimensions (**outside diameter and wall thickness**), a magnet test, and a hardness test shall be performed. The magnet test will verify the presence of iron. Hardness value will be the average of **3** tests at random locations on each pipe brace sampled. Because this item is loaded to less than 50% of available capacity and is critical only on the end sets in a series, the inspection/test population shall be based on the **Reduced** Sampling Plan of EPRI NP-7218, Table 2-1. Defects may be cause for rejection of a lot, and will result in increased sampling frequencies on that lot (if not rejected) and on subsequent lots until satisfactory evidence of a history of successful results are again achieved (to be addressed in Constructor's A/E approved Sampling Plan).

WORKSHEET FOR IDENTIFYING CRITICAL CHARACTERISTICS FOR A CGI

Parent Component: Tie Rod Assembly
Part/Item: Tie Rod Shims and Washers

1. *What is the Function of the Item and how could it fail in service?*

   The tie rod shims and washers will be under compression when the tie rod is tensioned to ensure firm contact between the tie rod nut and/or the pipe brace and the web of the steel set. The tie rod shims and washer could fail in compression due to the tension in the tie rod. However, failure of the tie rod shim or washer would not result in failure of the overall tie rod nor the tie rod assembly. Therefore, since failure of these items is unlikely and will not result in failure of the tie rod, shims and washers are not critical to the performance of the tie rod assembly and material dedication is not required.

2. *Based on the Safety-related Function of the item, what characteristics are considered critical to ensuring the item performs its Safety-related Function?*

   A. *Product Identification Characteristics:*
   - N/A

   B. *Physical Attributes:*
   - N/A

   C. *Performance Characteristics:*
   - N/A

3. *How will the critical characteristics of item 2, above be verified?*

   N/A

4. *What inspection, testing and sampling methods, and sample populations are recommended?*

   N/A