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<b>Nuclear Facility Construction – Structural Steel Criteria and Review Approach Document</b>		
Authorization and Approval	 C.E. (Gene) Carpenter, Jr. Director Office of Nuclear Safety and Environmental Assessments  Date: April 1, 2019	 Lead, Sarah C. Rich Nuclear Engineer  Date: April 1, 2019

## 1.0 PURPOSE

The mission of the U.S. Department of Energy (DOE) Office of Environment, Safety and Health Assessments (EA-30) is to assess the effectiveness of safety and emergency management systems and practices used by line and contractor organizations and to provide clear, concise, rigorous, and independent evaluation reports of performance in protecting workers, the public, and the environment from the hazards associated with DOE activities.

In addition to the general independent oversight requirements and responsibilities specified in DOE Order 227.1A, *Independent Oversight Program*, this criteria and review approach document (CRAD), in part, fulfills the responsibility assigned to EA in (reference source document) to (paraphrase responsibility or requirement).

The CRADs are available to DOE line and contractor assessment personnel to aid them in developing effective DOE oversight, contractor self-assessment, and corrective action processes. The current revision of EA's CRADs are available at <http://www.energy.gov/ea/criteria-and-review-approach-documents>.

## **2.0 APPLICABILITY**

The following CRAD is approved for use by the Office of Nuclear Safety and Environmental Assessments (EA-31) at DOE Hazard Category 1, 2, and 3 facilities.

## **3.0 FEEDBACK**

Comments and suggestions for improvements on this CRAD can be directed to the Director, Office of Environment, Safety and Health Assessments.

## **4.0 CRITERIA AND REVIEW APPROACH**

The review focuses on the implementation of construction activities for structural steel in DOE Hazard Category 1, 2, and 3 facilities; including qualification of materials, fabrication of structural steel members, the onsite receipt inspection program, storage of materials, structural steel erection, field welding, and related quality assurance activities. The review will evaluate the effectiveness of contractor programs and processes for receipt, erection, and inspection of steel meeting structural design requirements. The following objectives provide a set of criteria and suggested lines of inquiry to assess structural steel construction activities. The structures may or may not be identified as safety class structures. The objectives of this CRAD are designed as standalone sections to be used in any combination based on the need of the specific assessment and the work in progress at the time of the assessment.

### **OBJECTIVES**

**SS.1: Applicable DOE directives and industry standards are referenced in design basis documents and contract specifications. Project documents, including specifications, drawings, and procedures, specify and control the construction and inspection processes. (10 CFR 830.122(d) and 10 CFR 830.122(e))**

#### **Criteria:**

1. Quality assurance programs are established and implemented in accordance with DOE 10 CFR 830, Subpart A, *Quality Assurance Requirements*; ASME NQA-1, *Quality Assurance Requirements for Nuclear Facilities Applications*; DOE Order 226.1A, *Implementation of DOE Oversight Policy*; and, either of the following DOE Orders specified in the Contractor Requirements Documents (CRD) and incorporated in the contract: DOE Order 414.1C, *Quality Assurance*, or DOE Order 414.1D, *Quality Assurance*, plus other requirements specified in the CRD which may include Subparts of NQA-1, Part II and NQA-1, Part III.
2. The construction drawings and specifications translate design requirements into details that define the technical requirements for fabrication and installation of structural steel. The procurement specifications for structural steel and associated hardware, such as weld filler materials and fasteners

(i.e., high strength bolts, nuts and washers), are consistent with the design basis documents. The specifications provide for control of design changes and the issuance of design change notices. (10 CFR 830.122(d))

3. Procedures, specifications, and drawings ensure that structural steel construction and inspection activities are controlled and performed in accordance with applicable requirements. Construction procedures must reference the required inspection hold points and must also address the Quality Assurance (QA) department authority to stop work (10 CFR 830.122(d)).

**SS.2: Specifications for procurement of structural steel and hardware items required for structural steel construction are consistent with design basis documents and meet applicable industry standards. (10 CFR 830.122(g))**

**Criteria:**

1. Procurement specifications are consistent with design basis documents and contract requirements for materials such as structural steel members, fasteners (high strength bolts, nuts, and washers), weld filler materials and welding supplies, and miscellaneous items such as shims, base plates, and anchor bolts.
2. QA program requirements for suppliers of components required for structural steel construction are clearly stated in the procurement documents. The suppliers are on the contractor's approved suppliers list and their QA programs have been audited by either the contractor or by an approved third party to validate the implementation of the suppliers' QA program.
3. A commercial grade dedication program has been established by the contractor to demonstrate that a commercial grade item is suitable to satisfactorily perform its safety function. See NQA-1, Part II, Subpart 2.14 for guidance in evaluating commercial grade items.
4. Structural steel is fabricated in accordance with the American Institute of Steel Construction, *Manual of Steel Construction*. The structural steel fabricator<sup>1</sup> has established the following controls to ensure that structural steel members comply with design requirements:
  - An approved NQA-1 quality assurance program that has been audited by the general contractor or a designated third party.
  - Structural steel fabrication drawings approved by design engineering.
  - Bulk steel shapes are purchased by the fabricator from suppliers that have approved QA programs that were audited by the contractor, fabricator, or designated third party.
  - A receiving inspection program that verify steel shapes delivered by steel supplier meet specification requirements.
  - A welding program and a weld inspection program that meets the requirements of the American Welding Society (AWS) Code.
  - A quality control inspection program for inspection of fabricated beams, columns, and other members to assure that steel members were fabricated within dimensional tolerances, bolt holes are properly sized and located, and welds meet requirements shown on design drawings and the AWS Code.

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<sup>1</sup>Structural steel is typically furnished by an offsite steel supplier who prepares fabrication drawings, also called shop drawings, from the design drawings; purchases various sizes of structural steel shapes; and fabricates the beams, columns, and other shapes shown on the drawings from the purchased structural steel.

**SS.3: The contractor has established and implemented a program to receive, inspect, and store structural steel and hardware required for structural steel construction work that are supplied by offsite vendors. (10 CFR 830.122(h))**

**Criteria:**

1. The contractor has established and implemented a program for receiving and inspecting components required for structural steel construction activities, including prefabricated structural steel members, pieces of bulk structural steel, and other hardware items such as weld filler materials, anchor bolts, and fasteners, to ensure the components comply with the procurement specifications. The receipt inspection program includes inspection for damage and condition of packaging for hardware items. Receipt inspection records are generated to document condition and quality of the components received.
2. Documentation shows structural steel and hardware for structural steel construction delivered to the project comply with the physical, mechanical and chemical properties specified in the procurement specification, the materials purchased meet appropriately specified quality levels, and are certified as such by suppliers. The documentation should include records of shop inspections, including NDE of welds, qualifications of welders and inspection personnel.
3. The receipt inspection procedures specify appropriate methods to report suspected counterfeit items to DOE and the DOE Office of Inspector General. See DOE Handbook DOE-HDBK-1221-2016, *Suspect/Counterfeit Items Resource Handbook* for guidance.
4. Manufacturer's records that document the chemical and physical properties of structural steel, fasteners, and weld filler materials demonstrate that these items meet the requirements specified by the American Society for Testing and Materials (ASTM) specification referenced in the design specifications.
5. QA/Quality Control (QC) records documenting that structural steel and hardware required for structural steel construction comply with project specification requirements must be retained and stored in accordance with the NQA-1, Requirement 17. Records must be identifiable and retrievable.
6. The contractor has established and implemented a program that designates methods to store and protect structural steel members and hardware from damage or deterioration. Non-conforming components are clearly identified and stored in an area segregated from qualified components. The system used to identify components while they are in storage will retain the identity of the components and not deteriorate due to weathering while the components are in storage.

Additional Considerations

- Fasteners and weld filler materials are supplied by vendors on an approved suppliers list established by the contractor's procurement program.
- Weld filler materials (electrodes) and other welding supplies are certified by the manufacturer and weld filler materials (electrodes) are stored in sealed containers per manufacturer's specifications.
- Fasteners are certified by the manufacturer and clearly marked to indicate grade and type.
- Representative samples of each lot and size of high strength structural steel bolts are tested using a hydraulic tensioning calibrator, also known as a tension-indicating device.

- Third-party inspection organizations have an approved NQA-1 Quality Assurance program and their inspection personnel must be qualified in accordance with the applicable requirements of ASME NQA-1.
- Receipt inspection procedures should include positive materials identification methods to evaluate selected components.
- Structural steel is supported on timber or curbing to allow air circulation and to avoid trapping water, preferably on a well-drained gravel or paved surface.
- Unpainted structural steel is covered when stored outside (Level C storage) for protection from moisture.
- Fasteners are stored in closed containers and protected from dirt and moisture by storing in a Level C storage area.

**SS.4: The contractor has established a program and controls to perform onsite fabrication of structural steel members and perform onsite modifications to vendor supplied structural steel members in accordance with the NQA-1 requirements. See Section SS.6 for welding criteria.**

**Criteria:**

1. Perform onsite fabrication of structural steel members in accordance with construction drawings and specifications issued by the design engineering organization.
2. Perform modifications to vendor supplied structural steel members in accordance with a design change approved by design engineering. Modification details must be shown on construction drawings prepared and approved by the design engineering organization.
3. A quality control inspection program for inspecting onsite structural steel member fabrications and modifications is required to ensure these activities are performed in accordance with the QA program. QC inspectors performing inspections of these activities, including welding, configuration, and material traceability are required to be independent and qualified in compliance with NQA-1.
4. Records are maintained documenting on-site fabrication work and inspection activities.

**SS.5: Structural steel and components for anchoring structural steel are erected and installed in accordance with approved design drawings. (10 CFR 830.122(e))**

**Criteria:**

1. Structural steel is erected in accordance with the American Institute of Steel Construction, *Manual of Steel Construction*. The erected structural steel is configured (i.e., correct size, shape, orientation, location, and plumb or level) in accordance with design drawings

Additional Considerations for erection of structural steel:

- Are members free of damage?
- Do fit-up and alignment tolerances, length, depth, and straightness of structural members and alignment of bolt holes meet specification requirements?
- Are instruments used to control alignment, plumb, and level during erection calibrated?
- Are joint contact surfaces free of burrs, dirt oil, and contamination, and are they solidly seated?

2. The fabrication and installation of structural steel for nuclear facilities complies with the applicable Codes specified in the contract documents, for example, the American Institute of Steel Construction (AISC), and other Codes, referenced in the CRD.
3. Components that anchor structural steel to the building structure, such as anchor bolts and plates embedded in concrete, are fabricated and installed in accordance with the details shown on the design drawings. The details for connection of structural steel to anchor bolts (typically double nuts) and embedded plates (weld size, length, and type) are as specified on the design drawings.
4. Installation of bolts in structural steel connections comply with the AISC 348 and/or Research Council on Structural Connections *Specification for Structural Joints Using High Strength Bolts*. The type of bolts and bolt tensioning methods are performed in accordance with design documents.

Additional Consideration for Installation of Fasteners:

- Are fasteners snug tight prior to final tightening of bolts?
- Manufacturers apply a protective coating to fasteners to prevent corrosion and lubrication to facilitate installation. Some types of fastener components can be cleaned in the field if necessary, to remove dirt or rust, and re-lubricated in accordance with manufacturer's instructions. A representative sample of re-lubricated fasteners must be re-tested with a tension-indicating device. Tension control (twist-off) fasteners can only be re-lubricated by the manufacturer. Are a representative sample of the re-lubricated fasteners tested with a tension-indicating device?
- Have samples from each lot of fasteners been tested using the tension-indicating device, prior to being released from storage for installation in the field, to verify that the pre-tensioning method will develop the minimum required bolt pretension? Are pre-installation test results documented? (AISC 348)
- For fasteners that are tensioned by use of a calibrated wrench, are representative samples of each size of fasteners tested each day using the tension-indicating device to establish the minimum torque necessary to demonstrate the installation method will develop the minimum required fastener installation tension (pretension)? (AISC 348)
- Is each joint type (i.e., snug-tightened, pre-tensioned, or slip-critical) clearly identified on the design drawings?
- Are craft and QC inspection personnel able to identify the joint type and required method for tensioning the bolts in each joint? (AISC 348)
- Are the correct size and type of fasteners installed and is the correct tensioning method, (snug tight, turn-of-the-nut, torqued with a calibrated wrench, direct tension indicators, or tension control (twist-off) bolts) and tightening sequence applied to each?
- Are washers on correct side of fastener (under turning element)?
- Do bolts have sufficient thread engagement?
- Do inspection and craft understand that bolts cannot be reused after they are tensioned and that bolts used as temporary erection bolts cannot be used as permanent bolts?

**SS.6: Field welding is performed by qualified welders using approved processes and methods. Welds are inspected by qualified nondestructive examination personnel, and records are maintained to verify welds meet specifications. (10 CFR 830.122(e) and (h))**

**Criteria:**

1. Welds on structural steel are performed according to a qualified process by a welder qualified in accordance with American Welding Society AWS D1.1, *Structural Welding Code-Steel*, or

equivalent. Welder qualification records are maintained that show welders are qualified per AWS D1.1.

2. Welding processes are qualified by a procedure qualification record (PQR) and the weld method is documented on a written welding procedure specification (WPS) as specified in AWS D1.1.
3. Nondestructive examination of welds is performed as specified and welds that do not meet the acceptance criteria are repaired and re-inspected.
4. Personnel who perform welding inspections are certified in accordance with an inspector training and qualification program that complies with NQA-1 and additional standards specified in ASME, American Welding Society Standard (AWS), or the American Society for Nondestructive Testing (ASNT).
5. Weld records identify weld location, type and size, identify filler material used, welder identification, materials joined, joint preparation, WPS, pre-heat (if applicable), type of NDE inspection performed, results, and inspector. Weld records are maintained to verify welds meet specification requirements.

Additional Considerations for welding.

- Do welder qualification records include results of test assemblies (coupons) that were tested to demonstrate welders are qualified per the AWS Code?
- Are the correct weld filler materials (electrodes) used as specified in the AWS Code and applicable PQR and WPS?
- Is storage and handling of welding materials in accordance with the manufacturer's recommendations and AWS Code?
- Are weld joints prepared as specified in the WPS (i.e., are they free of paint, oil, dirt scale, rust, moisture and other foreign materials), and are gaps between joints or faying surfaces (mating surfaces or faces of two metals placed in contact to form a joint connected by welding or bolting) within specification requirements?
- If applicable, is pre-heat, inter-pass temperature, and post-weld heat treatment performed in accordance with specification requirements?
- Is volumetric NDE performed on weld in accordance with AISC Code for specific types of welds designated, such as complete joint penetration welds loaded in tension and welds subjected to fatigue loading?

**SS.7: Quality control personnel are trained and qualified in accordance with industry standards.  
10 CFR 830.122(b)**

**Criteria:**

1. QC inspection personnel who perform inspections of structural steel construction work activities are qualified in accordance with the requirements of NQA-1, and the applicable Codes referenced in the CRD and contract documents regarding education, experience, training and certification. The QC inspector certification program should include written and practical exams that demonstrate their ability to perform their inspection activities. The QC inspectors are also required to pass an annual physical and eye exam.
2. The employing organization is required to verify the education and experience of QC inspectors and testing personnel.

3. In addition to the requirements stated in Criteria 1 and 2 above, NDE inspectors who perform inspections of structural steel welding activities are also required to be qualified and certified in accordance with the American Welding Society Code, AWS D1.1, and/or the American Society for Nondestructive Testing Standard SNT-TC-1A.
4. The number of qualified QC personnel at the construction site should be commensurate with the work in progress.
5. QC inspectors demonstrate adequate knowledge of the requirements of their work activities.
6. Records are to be maintained that document education, experience, training, results of written and practical exams and results of annual eye and physical exams.

**SS.8: Quality records documenting structural steel construction work and QC inspection activities are maintained in accordance with DOE Quality Assurance regulations. (10 CFR 830.122(d))**

**Criteria:**

1. Records are maintained documenting that structural steel has been installed in accordance with design requirements and that appropriate inspections have been completed. Records include those that document:
  - Structural steel erection.
  - Installation and tensioning of high strength bolts.
  - Field welding activities.
  - Structural steel fabrication records.
  - Receipt inspection records.
  - Material qualifications.
  - Records documenting qualification of materials.
  - QC and NDE inspector qualifications and certifications.
2. Records are legible, complete, and retrievable.
3. As-built drawings have been prepared that provide record of the installed structural steel.
4. Copies are kept of nonconformance/deviation records initiated to resolve deficiencies identified with structural steel construction activities, including description of corrective actions that resolved the deficiencies.
5. Records document QA audits and self-assessments associated with structural steel construction activities.

***REVIEW APPROACH***

Record Review:

- Construction specifications related to structural steel construction
- Structural steel construction procedures
- Structural steel drawings issued by design engineering for construction
- Design basis documents
- Design change documents
- Procurement specifications



- Receipt inspection records
- Structural steel shop drawings
- Weld procedure qualification records (PQRs)
- Welding procedure specifications (WPSs)
- Welder qualification records
- Records documenting welding, including weld travelers and NDE results
- Qualification records for QC and NDE inspection personnel.
- Records documenting quality of completed structural steel installation
- Results of tests performed by the tension-indicating device on fasteners
- QA surveillance/audit program and self-assessments for structural steel construction activities

Interviews:

- Construction Manager
- Construction supervisors
- Design Engineers
- Construction field engineers
- Construction craft (iron workers) and foremen
- Receipt inspectors
- Procurement supervisors
- Quality control supervisors and inspectors
- Welding NDE inspection personnel
- NDE level III

Observations:

- Examine storage of structural steel, fasteners, and weld filler materials.
- Accompanied by a receipt inspector, perform a walk down of the receiving facility and examine an ongoing receiving inspection, to observe receipt inspection methodology and documentation review.
- Examine the weld filler issue facility.
- Observe testing of fasteners on the tension-indicating device.
- Selectively walk down erected structural steel and compare the actual physical installation to details shown on the design drawings issued for construction.
- Observe ongoing construction work to determine if structural steel work activities and the quality of work meet the requirements of applicable specifications, procedures, drawings, and codes.
- Observe quality control (QC) inspection activities and examine completed structural steel work to assess the effectiveness of the QC program.
- Observe the controls for temporary erection bolts and verify temporary erection bolts are clearly identified.
- Examine records storage facility.

## INSPECTION GUIDANCE

The Construction Authorization Agreement, the CRD, the nuclear facility safety basis documents, and approved Project QA Program specify design, construction, and QA/QC requirements. The CRD lists the specific Codes, Standards, and DOE Regulations that are part of the project construction agreement (contract). These requirements are implemented in the construction specifications, drawings, work procedures, and QC/QA implementing procedures.

Industry codes for structural steel design and construction are ANSI/AISC 360-16, *Specification for Structural Steel Buildings*; ANS/AISC N690-18, *Specification for Safety-Related Steel Structures for Nuclear Facilities*; AISC 348, *Specification for Structural Joints Using High-Strength Bolts*; and the Research Council on Structural Connections (RCSC) *Specification for Structural Joints Using High-Strength Bolts*. In addition to copies of ANSI/AISC 360 and AISC 348, the AISC Steel Construction Manual contains tables with dimensions and properties of structural shapes, general design considerations for structural steel, and design criteria and design examples. Structural steel welding requirements are specified American Welding Society (AWS) D1.1, *Structural Welding Code*. The Codes and editions applicable to the project will be identified in the CRD section of the contract and the nuclear facility safety basis documents. If referenced in the CRD, additional QA requirements for structural steel are specified in NQA-1, Part II, Subpart 2.5, *Quality Assurance Requirements for Installation, Inspection, and Testing of Structural Concrete, Structural Steel, Soils, and Foundations for Nuclear Power Plants*.

The construction specifications must translate design requirements into details sufficient to define the technical requirements for structural steel construction activities. The specifications should provide for control of design changes and the issuance of design change notices. The review of procedures, specifications, and drawings should ensure that structural steel construction and inspection activities are controlled and performed in accordance with applicable requirements. QA/QC procedures should specify acceptance requirements and should specify the personnel and interface responsibilities required to define, control, and resolve field problems or design problems that occur during construction. QA/QC procedures must provide for effective inspections that will assure that work is performed in accordance with specification requirements. Construction procedures must reference the required inspection hold points and must also address the QA/QC department stop-work authority. The procedures should require verification of specified controls and should not be accomplished merely by surveillance. Records must document that work and inspection activities were performed in accordance with all applicable requirements.

Structural steel construction activities should be observed to ascertain they are consistent with standard industry practices. Observe the attitudes in work crews, and relations between construction personnel and QA/QC personnel. Determine whether the construction labor forces also perform their own checks of work as it is completed, or if they rely solely on QA/QC. Review the experience, training, and number of foremen and superintendents overseeing structural steel construction activities. Observe QA/QC inspectors when they are performing inspections and check-offs. Do the inspectors perform their inspections sequentially as work is being performed?

### Fabrication of Structural Steel and Qualification of Materials

The structural steel is typically furnished by a steel supplier who prepares fabrication drawings from the drawings issued by engineering design for construction, purchases structural steel components from an approved vendor, cuts the components to the required length, width, thickness, drill/punches holes for bolts, welds clip angles, stiffener plates and other components to beams and columns so steel can be installed at the construction site with a minimum of field modifications. Each member is uniquely identified using a technique which will permit member identification through the installation and final inspection process. The fabricator may also design connection details, specifying type of joint, number

and size of bolts, and weld details. The structural steel fabrication drawings and connection details must be approved by the design engineering organization. The steel fabricator must be on the Approved Suppliers List and should have an approved QA program; otherwise, the General Contractor will be responsible for inspecting and accepting work performed by the steel fabricator.

Requirements for structural steel materials will be specified in the CRD, the nuclear facility safety basis documents, in the referenced Codes and Standards, and contract specifications. The structural steel materials include structural steel members (beams, columns, plates, and other shapes), fasteners (bolts, nuts, and washers), welding electrodes and other welding supplies, and miscellaneous items such as shims, base plates, and anchor bolts. Chemical and physical tests for all materials used must indicate that specifications have been met. The physical and chemical tests are required to be performed on each lot (batch) of materials. Test results may be provided by the steel manufacturers via certified materials test reports (CMTR), or may be performed at an independent testing laboratory. Fasteners are certified by the manufacturer, and grade and type are clearly marked on the bolts, nuts, and washers. Welding electrodes and other welding supplies are also certified by the manufacturers. Some hardware items may not be available from a supplier that does not have an approved QA program. In these cases, the hardware items can be approved using a commercial grade dedication process that complies with DOE regulations and Guides.

There have been significant problems in numerous industries with fasteners and other components such as valves and electrical breakers being supplied with fraudulent documentation and markings indicating that the components met various industry standards. These items are generally referred to as counterfeit. The contractor's procedures are required to notify DOE and the DOE Inspector General when suspected counterfeit fasteners and other components are identified.

The General Contractor is required to audit their suppliers through their vendor inspection program. The contractor's audit of the steel fabricator should verify the fabricator has an adequate QA program and is implementing the program. Key areas are verification that purchased structural steel components were supplied by a qualified steel supplier; documentation that physical and chemical tests were performed to show purchased steel meets appropriate AISC/ASTM requirements (either a CMTR or tests from an independent test laboratory); results of receipt inspection of base steel which should include check of mill tolerances for various size members; results of inspections that show fabricated components meet drawing and specification requirements, fabricator's welder qualification program, shop weld inspection results, audit of steel suppliers; and verification that fabricator's QC inspectors are qualified.

The steel fabricator's shop inspection program should include the following:

- Review of CMTRs from material suppliers.
- An inspection program that verifies dimensions of structural steel shapes received from the steel manufacturer or supplier for assuring structural shapes meet AISC requirements.
- Inspection of shop welds to assure shop welds meet AWS requirements.
- Inspections that verify fabricated beams, columns, and other members were fabricated within specified tolerances, and that bolt holes are properly sized and located, including proper edge distances.

### Storage

Structural steel materials need to be clearly identified through use of an adequate marking system. Paper tags are generally not sufficient to maintain identification through installation and final inspection. When structural steel is received onsite, a receipt inspection is performed to assure that documentation is supplied to demonstrate that the steel members comply with project requirements. This documentation includes CMTRs and inspection releases from the vendor. The steel is inspected for damage and verification that it is properly identified. If the steel is damaged, or documentation is missing or inadequate, the item is

considered nonconforming. A non-conformance document should be initiated to document and disposition the problem. Non-conforming or unqualified materials are required to be segregated from qualified materials. The CMTRs and inspection documentation which accompanied the shipment should be reviewed in detail by a subject matter expert to assure the materials meet specification requirements.

Structural steel is required to be supported on timber or curbing to allow air circulation and to avoid trapping water, preferably on a well-drained gravel or paved surface and not be in contact with ground in the storage area. Painted structural steel requires Level D storage (outside, uncovered). Components which have not been painted require Level C storage (outside and covered) for protection from moisture.

Fasteners are stored in closed containers for protection from dirt and moisture. Containers are also required to be stored in a protected shelter, minimum Level C storage area (outside and covered), and not in contact with ground. The manufacturers generally apply a protective coating to fasteners to prevent corrosion and facilitate installation. If the containers are opened or damaged upon receipt or in storage, the fasteners in the damaged/open containers are considered to be non-conforming, requiring evaluation to determine corrective actions, which may involve cleaning and re-lubrication. Fasteners that are re-lubricated are required to be re-tested with a tension measuring device. Tension control (twist-off) bolts cannot be re-lubricated. Fasteners that are not considered acceptable for permanent installation and should be scrapped or may be used as temporary erection bolts.

The RCSC Specification states that “only those fasteners that can be installed during the work shift shall be taken from protected storage. Fastener components that are not incorporated into the work shall be returned to protected storage at the end of the work shift.

Weld filler materials (electrodes) are stored in sealed containers, per manufacturer’s requirements. If the containers are opened or damaged upon receipt or in storage, the electrodes in the damaged/open containers are considered non-conforming. After filler materials are removed from original packaging, they are required to be protected or stored in an oven so welding characteristics are not changed.

Storage controls, materials identification, protection, and segregation are required to be maintained until installation in the facility and final inspection and acceptance. For additional information on the requirements for receiving and storage of components at nuclear facilities, see NQA-1, Part II, Subpart 2.2, Quality Assurance requirements for Packaging, Shipping, Receiving, Storage and Handling of Items for Nuclear Power Plants.

### Structural Steel Erection

Structural steel is erected in accordance with design drawings and approved design documents, including design changes. The structural steel is attached or fastened to the building with anchor bolts that were embedded in the concrete base mat or walls or embedded plates that are fabricated with studs and installed prior to concrete placement. Information on the stud welding process and inspection methods see the section on stud welding in AWS Welding Handbook.

The most significant problems that occur during structural steel erection usually involve alignment and plumbness deficiencies, and fit-up problems at joints. Misalignment of bolt holes is also a common problem. These problems need to be documented and submitted to design engineering for resolution. Unauthorized modifications to steel members to obtain a snug fit at a connection or to correct alignment problems is an unacceptable practice. Joint contact surfaces, also referred to as fraying surfaces, are required to be free of burrs, dirt oil, and contamination. Connection parts need to fit up within specification tolerances. Excessive gaps will affect tension in bolts and weld quality.

### Bolt Installation and Tightening

A tension calibrator is a hydraulic device that indicates the pretension in a bolt. The tension calibrator must be calibrated. The tension calibrator tests on the as-received fasteners is required to be performed prior to installing the fasteners. This testing is performed to confirm the suitability of the completed fastener assembly including lubrication of the fastener and the tensioning procedure used by the ironworkers. A sample of each grade and size fastener of each lot from fastener assembly is required to be tested in a tension calibrator to verify that the bolt tensioning method develops the minimum required pretension. The test methods are discussed in AISC 348 and the RCSC Specification. Pre-installation test results must be documented.

In addition to the testing of as-received fasteners using the tension calibrator discussed above, additional testing is required when fasteners are tensioned using a calibrated torque wrench. Each day fastener tensioning is to be performed using a torque wrench, a sample of at least three bolts of each type is required to be tested in the tension calibrator device, in order to establish the torque value necessary to apply the required pre-tension value to the fastener assembly on that day.

The joint type must be clearly identified on the design drawings. Joint types include snug-tightened, pre-tensioned, or slip-critical. AISC 348 and the RCSC Specification specify the requirements for installation and tightening of bolts in each connection type. The joint type must be clearly indicated on the design drawings so that craft and QC inspection personnel can readily identify the joint type and required method to be used to tension the bolts in each joint. QC inspectors should witness fastener tensioning for turn of the nut and calibrated wrench tensioning. For joints with twist-off type fasteners and direct-tension indicator fasteners, the QC inspectors should witness the pre-installation testing discussed above and monitor the work in progress. The final twist-off of the splined ends of tension control bolts should be completed within a reasonable time after removal from protected storage.

All bolts should have full thread engagement. Requirements for installation of washers are also specified in AISC 348 and the RCSC Specification. Bolts cannot be reused after they are tensioned. Bolts used as temporary erection bolts cannot be used as permanent bolts and should be clearly marked so they are not used as permanent bolts.

### Field Welding

Welding of structural steel is performed in accordance with the AWS Structural Welding Code, AWS D1.1. Refer to the AWS D1.1 Code for detailed requirements. Supplemental criteria for inspection of welds is contained in NCIG-01, *Visual Weld Acceptance Criteria for Structural Welding at Nuclear Power Plants*. The following are minimum requirements to insure a good quality welding program. The welding process (type of joint) is qualified in a procedure qualification record (PQR). The weld method is documented on a written welding procedure specification (WPS). All welders are qualified per the AWS Code, which requires preparation of test assemblies (coupons) which are inspected and tested.

Weld filler materials (electrodes) used are as specified in the AWS Code and applicable WPS and PQR. Storage, handling, and issue of welding materials are controlled per AWS requirements. Weld joints are prepared as specified in the WPS, are free of paint, oil, dirt scale, rust, moisture and other foreign materials, and gaps between fraying surfaces do not exceed specification requirements. Thermal (reheat, interpass temperature control, and post weld heat) treatment of welding is performed in accordance with AWS requirements. The welding process and equipment used are as specified in PQR and WPS. All welds are inspected by qualified NDE inspection personnel who are required to be qualified in accordance with either AWS D1.1 or SNT-TC-1A. A document typically referred to as a weld traveler is issued to document each weld or group of welds. The locations of welds are shown on a weld map which is a permanent record. The weld traveler identifies the weld location, type and size, identifies the filler

material used, the identification of the welder, materials joined, joint preparation, the PQR and WPS, thermal treatment, NDE performed and results, and identification of the NDE inspector.

The primary NDE method used to inspect structural steel welds is the visual inspection method. Visual inspection criteria is specified in AWS D1.1. Other NDE methods that are required by the AISC Code for specific types of welds should be indicated on the design drawings and/or specifications. Examples are complete joint penetration welds loaded in tension and welds subjected to fatigue loading that require volumetric NDE.

#### Qualifications of QC personnel

The qualifications (education and experience) of inspection personnel must be verified by the employing organization. Personnel qualifications must be supported by documentation. NDE welding inspection personnel are required to be qualified in accordance with AWS D1.1 or SNT-TC-1A. Inspectors who perform inspection of structural steel need to be certified as civil inspectors in the area of structural steel. All inspectors are required to pass an annual eye exam and be physically able to perform their duties. The minimum education and experience requirements for inspection personnel are specified in ASME NQA-1, AWS D1.1, and SNT-TC-1A.

#### Quality Records

Sufficient records are required to document that structural steel was erected in accordance with the design drawings and specifications. Records are required to document qualification of materials, installation of steel, connection details, and field welding activities. The records should indicate the actual conditions encountered in the field and provide adequate documentation of work and inspections. Records should include sufficient detail to document the results of inspections; and repairs, if necessary were completed in accordance with design requirements. Records should be legible, complete, reviewed by QC and/or engineering personnel, and readily retrievable. Training and qualification records for craft and QC inspection personnel are also required to be maintained. Additional records required to be maintained are those that establish that the required audits were performed and that deficiencies identified during audits were corrected.

#### Prevalent Errors and Recent Concerns

This section is included to provide background for inspectors on past structural steel construction problems that have been identified and on certain areas that should be more closely scrutinized. (Note - These are not listed in order of their perceived importance to safety.)

Inadequate QA/QC records documenting structural steel work activities

- Incorrect bolt type, mismatched bolts and nuts, missing washers, or missing bolts.
- Damaged members or members not fabricated to drawing requirements.
- Missing or defective welds. Defective welds included undersized welds, welds with excessive undercut, excessive porosity, slag or impurities, or incorrect type of weld.
- Improper enlarging of undersized bolt holes, flame cut holes.
- Installation of incorrect members, missing members, or altering members without design approval.
- Materials improperly stored.
- Counterfeit fasteners.
- Fasteners not tightened to specification requirements, e.g., loose nuts. In some cases, uncalibrated torque wrenches were used to tighten fasteners, or fasteners were not brought to snug tight condition

prior to tightening. Other problems were result of using rusty fasteners, or fasteners where manufacturer applied lubricants deteriorated.

- Installing tension control (twist-off) fasteners in the work and failing to perform the final twist-off of the splined ends for an extended period of time, resulting in the fasteners being exposed to the elements and deterioration of the factory applied lubrication. Fasteners required replacement.
- Inadequate design
- Attachment of supports for other equipment to structural steel without design approval, leading to possible overloading of steel structures. Unauthorized use of permanent structural steel for rigging/hoisting of equipment.
- Deficient alignment or fit-up for welded connections.
- Failure to perform pre-installation verification of fasteners.
- Problems with anchorage of steel beams or columns to concrete structures.
- QC inspections not done conscientiously, or inspections performed by unqualified personnel.
- Intentional violation of work procedures by craft personnel to avoid rejection of their work or to simplify their work.
- Construction personnel and supervision intimidation of QA/QC inspectors.

## REFERENCES

Code of Federal Regulations 10 CFR 830.122, Quality Assurance Criteria for DOE Facilities.

American Society of Mechanical Engineers (ASME)

ASME NQA-1, Quality Assurance Requirements for Nuclear Facility Applications.

American Institute of Steel Construction

Manual of Steel Construction

AISC 348, Specification for Structural Joints Using ASTM A325 or A490 Bolts

American Welding Society (AWS)

AWS D1.1, Structural Welding Code - Steel.

American Society for Non-Destructive Testing

SNT-TC-1A, Recommended Practice No. SNT-TC-1A Non-Destructive Testing

American Society for Testing and Materials International Standards

Specific ASTM standards for chemical and physical requirements for structural steel, fasteners, and weld filler materials will be listed in the specifications. These Standards specify the test methods and acceptance criteria for materials testing.

Research Council on Structural Connections

Specification for Structural Joints Using High-Strength Bolts

## Attachment A: Guidance and References

### NRC Publications

U.S. Nuclear Regulatory Commission, Regulatory Guide 1.199, Anchoring Components and Structural Supports in Concrete.

### Others

Nuclear Construction Issues Group, NCIG-01, Visual Weld Acceptance Criteria for Structural Welding at Nuclear Power Plants

American Concrete Institute (ACI) 349, Code Requirements for Nuclear Safety-Related Structures (code used for design of concrete anchorage and embedments for attachment of structural steel to the building structure).

For information and standards for studs and stud welding (proprietary name: Nelson Studs), which are used to secure embedded plates to concrete structures, refer to the Welding Handbook, published by the American Welding Society.□