U.S. Department of Energy Office of Safety and Emergency Management Evaluations Criteria Review and Approach Document	Subject: Nuclear Facility Construction – Piping and Pipe Supports Acting Director, Office of Safety and Emergency Management Evaluations Date: March 29, 2012 Criteria Lead, Nuclear Facility Construction – Piping and Pipe Supports Date: March 29, 2012	HS: HSS CRAD 45-52 Rev: 0 Eff. Date: March 29, 2012 Page 1 of 15

1.0 PURPOSE

The mission of the Office of Safety and Emergency Management Evaluations (HS-45), within the Office of Health, Safety and Security, is to assess the effectiveness of controls used by field organizations to protect our workers, the public, and the environment from the hazards associated with activities at Department of Energy (DOE) sites. This mission includes independent assessment of the quality of work performed during construction of DOE nuclear facilities. The purpose of this Criteria Review and Approach Document (CRAD) is to define the inspection criteria for review of piping and piping supports at a nuclear construction facility/site. Our Inspection Criteria, Approach, and Lines of Inquiry are for internal use and also are available for use by DOE line and contractor assessment personnel in developing and implementing effective DOE oversight and contractor self-assessment and corrective action processes on this WEB page.

2.0 APPLICABILITY

The following Inspection Criteria document is approved for use by the Office of Health, Safety and Security.

3.0 FEEDBACK

Comments and suggestions for improvements on these Inspection Criteria, Approach, and Lines of Inquiry can be directed to the Acting Director of the Office of Safety and Emergency Management Evaluations on (301) 903-5392.

NUCLEAR FACILITY CONSTRUCTION - PIPING AND PIPE SUPPORTS

Sample Selection

For the purpose of this criteria review and approach, this Criteria Review and Approach Document (CRAD) includes piping and pipe supports and attachments of the pipe supports to structures (concrete, structural steel, or embed plates). Pipe supports include rigid restraints, welded attachments to piping, struts, snubbers, spring cans, and constant supports. Inspection of pipe whip restraints are also included in this CRAD. Selection of nuclear facility piping systems for inspection should be based on a review of current construction status and information in the facility preliminary documented safety analysis to identify systems that are identified as safety class, safety significant, or important to safety. Sample selection should be focused on systems or parts of systems that have more critical safety functions, unique characteristics, or piping installed in areas that will have limited personnel access after operations. This CRAD does not address inspection of specialized welding activities such as bi-metallic welds or autogenous welding.

Inspection Criteria

The following DOE directives and industry standards are applicable to the extent that they are referenced in design basis documents and contract specifications and apply to the design, fabrication, installation, inspection, and testing of piping systems:

- Quality assurance programs are established and implemented in accordance with 10CFR830, Subpart A, *Quality Assurance Requirements,* ASME NQA-1, *Quality Assurance Requirements for Nuclear Facilities Applications,* DOE Order 414.1C, *Quality Assurance,* and DOE Order 226.1A, *Implementation of DOE Oversight Policy.*
- Piping systems and components are fabricated and installed in accordance with the American Society of Mechanical Engineers (ASME) standards.
- Individuals inspecting piping system fabrication and installation, including supports, are qualified in accordance with the requirements of ASME, American Welding Society Standard (AWS), or the American Society for Nondestructive Testing standards.

Inspection Activity

Observe construction activities and review records to assess the quality of piping system fabrication and installation to determine if requirements specified by design basis documents, contract specifications and drawings, and applicable codes and standards have been met:

- Review piping and pipe support procurement specifications and verify the specified technical requirements are consistent with the design basis documents for (1) piping and pipe support materials; (2) quality assurance (QA) requirements pertaining to traceability and certification of material properties (chemical and mechanical); (3) piping and pipe support fabrication; (4) control of special processes; (5) quality control (QC) inspection and non-destructive examination (NDE) requirements; and (6) preparation of QA records which document piping and pipe support materials and fabrication comply with applicable codes and QA requirements.

- Review piping and pipe support construction specifications and procedures. Verify they are adequate for (1) storage of piping and pipe support materials and components, including fasteners; (2) installation of piping and pipe supports; (3) identification and control of inspection hold points; (4) quality control inspection criteria; (5) pre-operational testing; and (6) control of design changes and evaluation of completed as-built piping systems.

- Observe ongoing and completed construction activities to determine if piping and pipe support installation meets the requirements of applicable specifications, procedures, drawings, and codes.

- If concrete expansion anchors are used on the project for anchoring pipe supports and restraints to concrete structures, observe installation and inspection practices. Review records documenting the qualification of the anchors and the training and qualification of craft personnel who install the anchors.

- Observe construction testing and pre-operational testing of piping systems.

- Observe QC inspection activities and examine completed piping and pipe support installation work to assess the effectiveness of the QC program. Review the qualifications (training and experience) of QC inspection personnel.

- Review records documenting quality of completed piping and pipe support installation. These records should include documentation of design changes and drawings documenting the as constructed piping system installation (as-built drawings).

- Review the QA surveillance/audit program for piping and pipe support construction activities.

Inspection Lines of Inquiry

- Fabrication of Piping, Pipe Supports and Qualification of Materials
  Piping and pipe supports may be fabricated by a vendor in an offsite shop, or in an onsite facility by a subcontractor. Materials such as piping spools, various types and shapes of steel, welding materials and other hardware used to fabricate piping and pipe supports are normally purchased from several different offsite suppliers, both foreign and domestic.
  - Are procurement specifications consistent with design basis documents and contract requirements for materials? Are requirements for certification of mechanical and chemical properties of the materials used for fabrication of piping and pipe supports, including maintaining traceability of the materials, specified in the procurement specifications? Note: Procurement programs and processes may have been previously assessed pursuant to HSS CRAD 45-12, *Nuclear Safety Component and Services Procurement Inspection Criteria, Inspection Activities, and Lines of Inquiry*, or assessed by DOE site office representatives. Review documentation of these assessments prior to performing this Inspection Line of Inquiry activity to avoid duplication of inspections.
  - Are the requirements for the fabricators' shop inspection and quality assurance programs, including NDE, clearly stated in contract documents? Note: These fabricators may use third party inspection organizations to perform shop inspections. The third party inspection organization must have an approved NQA-1 Quality Assurance program and their inspection personnel must be qualified in accordance with the applicable requirements of ASME, AWS, and the American Society for Nondestructive Testing standards.
  - Have onsite and offsite organizations fabricating piping and pipe supports established the following controls to ensure the quality required by design documents:
    - An approved NQA-1·quality assurance program that has been audited by the general contractor or a designated third party;
    - Preparation of piping and pipe support fabrication drawings approved by the design engineering organization;
    - A receipt inspection program to verify purchased materials meet purchase specification requirements;
    - A quality control inspection program for inspection of piping and pipe support fabrication, including welding, configuration, and material traceability.

    - A welding program and a weld inspection program that meets applicable code requirements; and
    - An adequate number of qualified QC inspectors?
  - Do materials purchased meet appropriately specified quality levels and are certified as such by suppliers?
  - Are weld filler materials (electrodes) and other welding supplies certified by the manufacturer?
  - Are manufacturers/suppliers of materials on the project's approved suppliers list and have audits been performed by either the general contractor, DOE, the piping/pie support subcontractor or by an approved third party to validate the certifications furnished by these vendors?

- Storage of Piping and Pipe Support Components
  Note: Various materials and components may be delivered to an offsite material handling and storage yard for future transfer to the project site or directly to the project site. The Lines of Inquiry below apply to both locations:
  - Is the receipt inspection program adequate to ensure piping and pipe support components delivered to the project comply with the project specifications? Does the documentation demonstrating qualification of piping and pipe supports traceable, and has it been reviewed by a qualified individual to verify compliance?
  - Does the receipt inspection program include inspection for damage and internal cleanliness of piping and other components?
  - Are receipt inspection records being generated to document condition and quality of materials received?
  - Are piping and pipe supports and components identified through use of an adequate system for identification of components which will not deteriorate when hardware is in storage?
  - Are piping and pipe supports stored under appropriately defined and designated conditions to protect items from damage or deterioration, including temperature and humidity? Are non-conforming materials clearly identified and stored in an area segregated from qualified materials?
  - Have in-storage maintenance recommendations from manufacturers been identified and applied to piping system components to ensure internal cleanliness, and prevention of corrosion, and mechanical damage?
  - Are any electrical components, e.g., valve operators and other sensitive components, associated with piping systems stored in accordance with vendor recommendations?
  - Are weld filler materials (electrodes) stored in sealed containers per manufacturer' requirements?
  - Are fasteners stored in closed containers and protected from dirt and moisture? Are containers stored in a protected shelter and are not in contact with ground?
  - Are filler materials stored in an oven or otherwise protected from moisture after removal from original packaging?
  - If applicable, is shelf life of consumables used for construction and inspection processes controlled?

- Piping System Installation
  - Are safety class boundaries described in design documents reflected accurately on construction drawings?
  - Are fabrication and installation drawings adequately controlled to insure the latest approved drawings are being used for construction, including timely posting of design changes?
  - Are sufficient cleanliness controls in place where necessary to prevent entry of foreign material into piping and attached system internals during installation and construction activities and to prevent handling damage during construction?

- Are piping systems configured (i.e., correct size, orientation, location and slope) in accordance with design drawings?
- Are valves (especially check valves) installed in the specified location and proper orientation (e.g., vertical or horizontal)?
- Do installation procedures limit use of jacks or rigging for pulling piping into position for support installation or welding so that cold spring allowances are not exceeded for that particular material, pipe size, and length of pipe run?
- Are the correct number and type supports and restraints installed at the locations and spacing specified on design documents?
- Are supports/restraints installed within tolerances specified on piping construction drawings?
- Are installed piping and components free of damage, corrosion, and arc strikes?
- Are shear lugs on piping located and welded per design drawings?
- Are specified clearances for thermal growth of piping/tubing provided on supports/restraints?
- Is field welding of piping controlled and is it performed in accordance with requirements of applicable ASME codes?
- Is insulation installed on piping or ducting as specified on design drawings?
- Are inspections of piping system installations performed when required and by qualified personnel?
- Are modifications to piping sections required by field conditions performed in accordance with applicable ASME code requirements, and have field changes been evaluated and approved by engineering?

- Pipe Support Installation
  - Are pipe support fabrication and installation drawings adequately controlled to insure the latest approved drawings are being used for construction?
  - Are supports and restraints fabricated/installed with design specified material sizes (e.g., plate and tubing thickness) and weld type (e.g., fillet or partial/full penetration) and size?
  - Are supports and restraints installed in the locations and spacing specified on design documents? Are the correct type and size support installed at each location?
  - Are installed piping and components free of damage, corrosion, and arc strikes? Have pre-installation checks been made to verify components are free from damage and functioning properly to ensure components are not installed if they are damaged?
  - Are specified clearances for thermal growth of piping/tubing provided on supports/restraints? Are there sufficient clearances between piping and pipe supports and other facility components such as cable trays, heating, ventilation, and air conditioning ducts, instrumentation, etc.?
  - Are provisions and controls provided for adjustments of snubbers, spring cans, and constant supports to settings specified on design drawings?
  - Are correct material and sizes of fasteners (bolts, nuts, washers) used for bolted connections and supports/foundations and are they installed properly (e.g., perpendicular to base plates, proper embedment, tight, and with full thread engagement)?
  - Are concrete expansion anchors of a type approved by design engineering, and have installation of the expansion anchors been inspected and accepted by QC?
  - Is field welding controlled on pipe supports performed in accordance with requirements of the AWS codes?
  - Are inspections of pipe supports performed by qualified personnel?
  - Are modifications to pipe supports required by field conditions performed in accordance with applicable ASME code requirements, and have field changes been evaluated and approved by engineering?

- Are anchor bolts, embedded plates, structural steel and other hardware used to anchor piping/piping supports to the building structure properly installed and located? Installation of anchor hardware has been inspected and accepted by QC. Post-erection activities, e.g., final alignment and plumb checks, base plate grouting, painting, etc., are completed.

- Field Welding
  - Are field welding processes used to fabricate piping systems and install pipe supports qualified as required by AWS or ASME codes with a procedure qualification record (PQR) and are weld methods documented on a written welding procedure specification (WPS)?
  - Do welder qualification records, including results of test assemblies (coupons), which were tested as required by the code, indicate that welders are qualified per the applicable code?
  - Are weld filler materials (electrodes) used as specified in the applicable codes and site weld procedures?
  - Are storage and handling of welding materials as specified by the manufacturer and AWS or ASME code?
  - Are weld joints prepared as specified in the welding procedures and specifications (i.e., are they free of paint, oil, dirt scale, rust, moisture, and other foreign materials), and are gaps between faying surfaces within specification requirements?
  - Are pre-heat, interpass temperature and post-weld heat treatment controlled in accordance with specification requirements?
  - Are welding process and equipment used as specified in PQR and WPS?
  - Are welds the size and type as specified on design drawings?
  - Are weld surfaces free of grooves, abrupt ridges, valleys, undercuts, cracks, discontinuities or other detrimental indications that appear to exceed code limitations?
  - Are welds inspected and are NDE inspection personnel qualified in accordance with either AWS, ASME, or SNT-TC-1A as required?
  - Are weld records maintained to verify welds meet specification requirements? Do these records identify weld location, type and size, identify filler material used, welder identification, materials joined, joint preparation, WPS, thermal treatment, NDE performed and results, and NDE inspector?

- Concrete Expansion Anchors
  These types of anchors may not be used on all projects. For guidance on qualification testing and inspection of concrete expansion anchors, including minimum recommended safety factors, refer to U.S. Nuclear Regulatory Commission IE Bulletin 79-02, Pipe Support Base Plate Design Using Concrete Expansion Anchors, including supplements.
  - Have documented qualification tests been performed to verify the load capacity of each type and size (diameter and length) concrete expansion anchor? Are appropriate safety factors applied to establish maximum anchor capacities (shear and tension) used for design?
  - Do construction procedures prescribe specific installation methods for each type and size of concrete anchor used on the project, including diameter and depth of drill hole in concrete, size of drill bit, drill hole tolerances (deviation from perpendicular and maximum diameter), controls for cutting rebar, cleaning of drill hole prior to anchor installation, setting of anchor, and application of torque or force to anchor?
  - Do construction procedures limit spacing between anchors, embedded plates, and anchor bolts placed before concrete pour, and minimum distance between concrete anchor and edge of concrete (edge distance)?
  - Are craft personnel who install anchors qualified through training and testing?
  - Are QC inspectors who inspect anchors trained and qualified in concrete expansion anchor installation inspection?

- Are records generated for each anchor installation? Do records show anchor location, type and size anchor, document installation process, torque/force applied to set anchor, identification of installer and QC inspector?

- System Testing
  - Have piping systems been properly cleaned and flushed to remove debris?
  - Have required pre-operational testing, such as pressure testing, flow testing, thermal expansion, and vibration been completed, inspected, and documented?
  - Have results of pre-operational tests been reviewed by a qualified individual (subject matter expert)?
  - Have testing discrepancies been identified, documented in the corrective action program, and resolved?

- Qualification of QC Inspection Personnel
  - Do training and qualification records confirm that NDE welding inspection personnel are qualified in accordance with AWS, ASME, or SNT-TC-1A as required?
  - Do QC inspection personnel demonstrate adequate knowledge of the requirements of their work activities?
  - Is the number of qualified QC personnel at the construction site commensurate with the work in progress?
  - Are QC inspectors who perform inspection of piping systems certified as in the area of mechanical/piping installation in accordance of Nuclear Quality Assurance-1 (NQA)?
  - Do qualification records document results of annual eye and physical exams for QC and NDE inspectors?

- Quality Records
  - Do records of piping and pipe support installation, including field welding activities, provide adequate documentation of work and inspections?
  - Are as-built drawings being maintained and updated to reflect actual installation?
  - Do records include sufficient detail to document the results of inspections were completed in accordance with applicable code requirements?
  - Are records legible, complete, reviewed by QC and/or engineering personnel, and readily retrievable?
  - Do receipt inspection records of fabricated items (piping spool pieces, supports/restraints), fasteners and weld materials confirm that required material characteristics (physical and chemical), performance tests, nondestructive test, and other specification requirements were met and traceability between hardware and records has been maintained?
  - Were hardware/materials supplied by vendors on an approved suppliers list established by the projects procurement program?
  - Do records confirm that piping systems have been installed in accordance with design requirements and that appropriate inspections have been completed?
  - Do nonconformance/deviation records include current status of reported conditions and do they include the status of corrective action or resolution?
  - Do training/qualification records establish that QA/QC personnel are adequately qualified to perform their assigned duties and responsibilities and that craft personnel have been trained in their assigned tasks? Are these records complete and current and show which activities inspectors are qualified to perform?

Inspection Guidance

The project safety design analysis, nuclear facility safety basis documents, and approved project QA program specify design, construction, and QA/QC requirements. These requirements are implemented through the construction specifications, drawings, work procedures, and QC/QA implementing procedures.

The Code of Federal Regulations 10CFR 830.122 and DOE, ASME, and AWS codes and standards specify Quality Assurance requirements for the fabrication, installation, inspection, and testing of piping and pipe support for nuclear facilities as required by project/site contracts. The editions and applicable sections of these codes and standards applicable to the project will be referenced in the specifications and the nuclear facility design safety basis documents. However, the project specifications, drawings, and procedures specify and control the construction and inspection processes. The construction specifications must translate design requirements into details sufficient to define the technical requirements for piping system fabrication and construction. The specifications should provide for control of design changes. QA/QC inspection and construction procedures should be reviewed and compared with the requirements of the applicable codes and specifications. QA/QC procedures must provide for effective inspections which will ensure that work is performed in accordance with specification requirements. Pre-operational testing procedures must provide verification that piping systems are operable. Qualified personnel should review test results and determine if results are acceptable. Construction procedures must reference the required inspection hold points and must also address the QA/QC department stop-work authority.

Fabrication of Piping, Pipe Supports, and Qualification of Materials

Requirements for piping and pipe support materials will be specified in the nuclear facility safety basis documents and contract specifications. The materials include various types of steels used to fabricate piping, pipe supports, and other components, including associated fasteners (expansion anchors, bolts, nuts, and washers), welding electrodes and other welding supplies, and other special equipment. Chemical and mechanical (physical) tests for all materials used must indicate that specifications have been met. Tests results may be provided suppliers and fabricators on certified materials test reports (CMTR), or may be performed at an independent testing laboratory. Welding electrodes and other welding supplies are certified by the manufacturers. Fasteners are also certified by the manufacturer, and grade and type are clearly marked on the bolts, nuts, and washers. The general contractor is required to audit their suppliers through their vendor inspection program. The contractor's audit of suppliers should verify the fabricator has an adequate QA program and are implementing these programs.

Piping is typically furnished by an offsite vendor (pipe supplier) who prepares fabrication drawings from the design drawings, purchases piping spool pieces from an approved vendor, cuts the spool pieces to the required length, makes any necessary bends, and fabricates a section of piping by welding a number of spool pieces together so the piping can be installed at the construction site with a minimum of field modifications. Each section of piping is uniquely identified using a technique which will permit member identification and traceability to the fabrication drawings throughout the installation and final inspection process. This includes maintaining material traceability, welding details, and detailed fabrication data such as identification of shop welds, NDE, and other inspection requirements, including identification of welders and inspectors. The majority of the piping fabrication is performed offsite in the vendor's shop. Piping for a project may be supplied by several different vendors and, in some cases, an onsite subcontractor may fabricate some piping sections. Frequently, piping sections require modification to accommodate construction or design changes. The modifications are normally performed onsite by either the general contractor or by a subcontractor.

Pipe supports include pipe hangers, rigid restraints, shock absorbing devices (snubbers or dynamic supports), and constant or variable-type supports. Supports may be fabricated in an offsite shop by a vendor or may be fabricated onsite by a subcontractor, or in a combination of both onsite and offsite shops. Many of the components used in supports, such as struts, spring cans, pipe clamps, clevises, etc., are purchased from vendors. Frequently, piping sections require modification to accommodate construction or design changes. The modifications are normally performed onsite by either the general contractor or by a subcontractor. Review the specifications and procurement documents for pipe support materials which include structural steel, fasteners (bolts, nuts and washers), weld filler materials, welding supplies, and miscellaneous items such as shims, base plates, and anchor bolts. Requirements for materials will be specified in the facility safety analysis report and contract specifications. Verify the pipe support fabrication drawings have been approved by design engineers, verify the pipe support fabricator has an approved NQA-1 quality assurance program, and that fabricated pipe supports are inspected prior to shipment to the construction site. The requirements for the pipe support fabricator's shop inspection program should be clearly stated in the contract documents. The fabricator's inspection program should include a receipt inspection program to verify purchased structural steel meets purchase specification requirements. Verify the fabricator's quality control inspection program includes controls for inspection of fabricated pipe supports to assure that the supports were fabricated within dimensional tolerances and welds meet requirements of the AWS Code. The fabricator may use a third party inspection organization to perform the shop inspections.

The piping fabrication drawings and pipe support drawings must be approved by the design engineering organization. The piping, pipe support supplier, and suppliers of other components associated with piping systems 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 suppliers of various components.

Review the general contractor's vendor inspection program to verify that the pipe support fabricator's QA program has been audited by the general contractor or a designated third party. Key areas are verification that structural steel were supplied by a qualified steel supplier; that physical and chemical tests were performed to show purchased steel meets appropriate American Institute of Steel Construction (AISC)/ASTM requirements (either a certified material test report (CMTR) or tests from an independent test laboratory); that receipt inspection of purchased structural steel included review of chemical and physical tests performed on steel; and that dimensions of steel were checked to verify sizes of the purchased steel meet mill tolerances specified in the AISC Steel Manual. The audit should also include a review of the pipe support fabricator's shop inspection program that provides verification that fabricated components meet drawing and specification requirements; a review of fabricator's welding program; a review of the shop weld inspection program; a review of the pipe support fabricator's audit of their steel suppliers; and verification that the fabricator's QC inspectors are qualified.

There have significant problems in numerous industries with fasteners being supplied with fraudulent documentation indicating the fasteners met various industry standards. These fasteners are generally referred to as counterfeit fasteners. There have also been problems with various types of steel and piping system components for which fraudulent documentation was provided as the basis for certification of quality. Refer to DOE G 414-1-3, "Suspect/Counterfeit Items Guide for Use with 10 CFR 830 Subpart A, Quality Assurance Requirements," for additional guidance on counterfeit items.

Storage

When materials are received onsite, a receipt inspection is performed to assure that documentation is supplied to demonstrate that the material and components comply with project specifications and that the correct material has been supplied and no shipping/handling damage has occurred. This documentation

includes CMTRs, certificates of conformance (COC), and inspection releases from the vendor. To the extent practical, materials in storage areas should be segregated by types of materials and sizes. If material is damaged or documentation is missing or inadequate, the item is considered nonconforming and must be documented in accordance with the project's corrective action program to initiate corrective action to disposition the problem. Non-conforming or unqualified materials are required to be segregated from qualified materials. The CMTRs, COCs, and inspection documentation which accompanied the shipment should be reviewed in detail by a subject matter expert to assure the materials meet specification requirements.

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.

Fasteners are stored in closed containers and protected from dirt and moisture. Containers are required to be stored in a protected shelter, minimum Level C storage area (outside and covered), and not in contact with ground. Note: Manufacturers generally apply a protective coating to fasteners to prevent corrosion and facilitate installation. If fastener components become dirty or rusty, they are not considered acceptable for permanent installation. Some fastener components may be used after cleaning and re-lubrication, depending on manufacturer's instructions.

Some components may require ongoing preventive maintenance during storage to protect surfaces from corrosion or other damage. Materials are required to be identified through use of an adequate marking system. Piping spool pieces are required to be capped to maintain internal cleanliness. Some components may require storage in a covered area such as under canvas or plastic waterproof tarps or in a warehouse for protection from the elements. All piping, pipe supports, and associated components are required to be stored on an adequate system of dunnage or timber cribbing so they are not submerged or partially submerged in standing water, or become coated with mud or debris. Stainless steel piping and materials should not be stored on timber dunnage treated with chemicals containing excessive levels of halogens and/or chlorides. Some sensitive instruments which are to be installed in piping systems may be required to be stored in a temperature and humidity controlled environment. There are also some components which may require additional storage controls, such as maintaining an internal purge with an inert gas in the component. The minimum requirements for storage may be specified by the manufacturer as a pre-requisite for maintaining the manufacturer's warranty. Storage controls, materials identification, protection and preventive maintenance, and segregation are required to be maintained until installation in the facility and final inspection and acceptance. Appropriate quality records are required to demonstrate compliance with storage requirements.

Piping Installation

Piping systems are installed in accordance with design drawings and approved design documents, including design changes. Piping installation is considered an iterative process which requires continued design updating due to the need to adjust pipe support locations due to interferences and other construction considerations. All construction field changes to piping systems, especially changes to support locations need to be documented and submitted to design engineering for approval. After completion of construction, accurate as-built drawing showing all as constructed details of piping systems need to be prepared by construction and approved by design. The as-built drawings will be used to evaluate required design modifications during facility operation. The as-built drawings are very important to document piping system construction details in areas where access is limited due to high or extremely high radiation levels after facility start-up.

The most significant problems that occur during piping and pipe support installation involve failure to detect material, fabrication, or installation deficiencies early in the process. Improperly qualified material, lack of material traceability, welding process or production problems not detected by QA/QC, mislocated pipe supports, improper installation and testing of expansion anchors, and undersized material thickness are examples of significant errors during installation of piping. These errors can result in construction delays resulting from the need to re-inspect completed work, requirements for design evaluations of defects, and extensive re-work and repairs. Inappropriate engineering involvement or actions in evaluating and dispositioning nonconformances and design changes and insufficient pre-operational testing are other areas of vulnerability.

Other deficiencies which can occur in piping installation are installing valves in incorrect locations and/or orientation, excessive arc strikes on piping, internal cleanliness problems, excessive cold springing of piping, and using outdated or uncontrolled drawings for installation.

Pipe Support Installation

Pipe supports include pipe hangers, rigid restraints, shock absorbing devices (snubbers or dynamic supports), stanchions, and constant or variable-type supports. Whip restraints are also included as pipe supports for the purposes of this CRAD. The locations and type of pipe supports for various piping sections are generally shown on isometric piping drawings. These drawings show the piping layout in three dimensions (x, y, and z co-ordinates), indicating lengths of pipe spools, location of field welds, and support locations. Pipe supports used on a project vary from standard supports to engineered supports. Standard supports are commonly used supports and are shown on generic detail drawings. These supports are designed to support piping within a range of applications. Standard supports may be vendor catalog items, structural shapes, or designed specifically for the project. The length of some members on the standard support can be adjusted as required to accommodate various configurations, with the support drawing showing maximum and minimum length of various support members. Engineered supports are uniquely designed and built for a specific location. Supports may be fabricated in an offsite shop by a vendor or may be fabricated onsite by a subcontractor, or in a combination of both onsite and offsite shops. Supports are fabricated using various structural steel shapes. Many of the components used in supports, such as struts, spring cans, pipe clamps, clevises, etc., are purchased from vendors. Frequently, piping sections require modification to accommodate construction or design changes. The modifications are normally performed onsite by either the general contractor or by a subcontractor.

Pipe supports are installed at the locations shown on the piping drawings and approved design documents. Installation requirements include correct support, orientation, location and fit-up and alignment, within specified tolerances. Verify supports are free of damage, corrosion, and arc strikes. It is important to inspect vendor supplied hardware such as snubbers, spring cans, struts, etc., to verify they are not damaged and properly adjusted prior to installation. In addition, provisions should be made to protect these items from damage during construction. Survey instruments used to control alignment and location of supports during installation should be calibrated.

Bolting

Fasteners are certified by the manufacturer. Grade and type are clearly marked on the bolts, nuts, and washers. Manufacturers furnish CMTRs to demonstrate compliance with project specifications and industry codes. Verify the manufacturer's/suppliers of these materials are on the project's approved suppliers list and that audits have been performed to validate the CMTRs furnished by these vendors. Verify connections are snug tight prior to final tightening of bolts. Correct fasteners (bolts, nuts, washers) are used. Washers are on correct side of fastener (under turning element). Bolts have sufficient thread engagement. Verify the following attributes: correct size and type fasteners, correct tensioning

(tightening) method, tensioning sequence, and tightened (torqued) to proper tension. Verify bolts have sufficient thread engagement. High strength structural steel bolts cannot be reused after they are tensioned.

Field Welding

Welding of piping systems is performed in accordance with the applicable ASME Boiler and Pressure Vessel Code. Welding of pipe supports and structural steel which provide the foundations for pipe supports is performed in accordance with AWS Structural Welding Code, AWS D1.1. Refer to these codes for detailed requirements. 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 applicable code, which requires preparation of test assemblies (coupons) which are inspected and tested. Weld filler materials (electrodes) used are as specified in the code and applicable WPS and PQR. Storage, handling, and issue of welding materials are controlled per code 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 code requirements. The welding process and equipment used are as specified in the PQR and WPS. All welds are inspected by qualified NDE inspection personnel who are required to be qualified in accordance with either the ASME or AWS Codes, 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. When welds require repair to meet quality requirements, the repair process is documented on a weld traveler.

Qualification 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, which include results of written and practical examinations. Inspection personnel are required to be periodically re-qualified. Individuals who inspect piping welds are required to be qualified in accordance with ASME or SNT-TC-1A for the type of welding specialty inspections they perform, e.g., visual, ultrasound, radiographic, etc. Piping welding inspectors may be qualified to perform visual inspections only or may have multiple certifications. Acceptance of all piping welds, including welding of attachments to weld, must be performed by inspectors qualified in accordance with ASME or SNT-TC-1A. The requirements for pipe support welds, which are classified as structural welds, are specified in AWS D1.1. Inspectors who perform inspection of piping and pipe support installation need to be certified as inspectors in the area of piping/mechanical. 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 piping systems were constructed in accordance with the design drawings and specifications. Records are required to document qualification of materials, piping fabrication, installation of piping and pipe supports, field welding activities, QC inspections, testing, and details of as-built conditions. 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 and nonconformance and deviation records which include corrective actions and resolution of identified deficiencies 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 piping and pipe support construction problems that have been identified and on certain areas that should be more closely scrutinized. Significant problems were identified at commercial nuclear power plants in 1979 with piping system and pipe support construction, piping design, QC inspection practices, and control, documentation and evaluation of field changes. These problems, which included all operating plants and plants under construction, had the potential to affect public health and safety if left uncorrected. The NRC issued Bulletins which required re-inspection of piping systems, re-analysis, and repairs. The programs to accomplish the required work to resolve the issues resulted in extended shutdowns of operating plants, delay in start-up in plants under construction, and extensive and costly modifications repairs. The Bulletins which describe the problems and recommended actions were IEB 79-02, Pipe Support Base Plate Design Using Concrete Expansion Anchors, and IEB 79-14, Seismic Analysis for As-Built Safety-Related Piping Systems.

Some other examples of piping and construction problems are summarized below (Note - These are not listed in order of their perceived importance to safety).

- Pipe supports were damaged or were not fabricated to drawing requirements.
- Records did not include sufficient detail to document the results of inspections were completed in accordance with applicable code requirements.
- Records were not legible, complete, reviewed by QC and/or engineering personnel, or readily retrievable.
- QA/QC records documenting piping and pipe support work activities were inadequate.
- Welds were missing or defective. Defective welds included undersized welds, welds with excessive undercut, excessive porosity, slag or impurities, incorrect type of weld, and welds with deficient alignment or fit-up.
- Weld filler materials were not properly controlled.
- Improper modifications were made to pipe supports.
- Pipe supports were fabricated with incorrectly sized members, missing members, altered members without design approval, and incorrect weld type, location, length or size.
- Improper storage of piping, pipe supports, and components.
- Counterfeit fasteners were used to assemble supports or attach pipe clamps to piping, or purchasing and using steel to fabricate piping or pipe supports with fraudulent documentation of chemical and physical properties.
- Multiple problems with bolting/fastener deficiencies were identified including use of incorrect bolt type, mismatched bolts and nuts, missing washers, or missing bolts, and bolts 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.
- Some designs were inadequate and design changes were not always properly controlled.

- Attachment of supports for other equipment to pipe supports were made without design approval, leading to possible overloading of pipe supports. Use of pipe supports for rigging/hoisting of equipment were not properly authorized.
- Concrete expansion anchors were not installed correctly.
- QC inspections not done conscientiously or inspections performed by unqualified personnel.
- Intentional violation of work procedures by craft personnel.
- Intimidation of QA/QC inspectors by construction personnel.

INDUSTRY EXPERIENCE

Counterfeit Items

DOE G 414-1-3, "Suspect/Counterfeit Items Guide for Use with 10 CFR 830 Subpart A, Quality Assurance Requirements." Note: See DOE Website for a training guide on counterfeit items.

NRC IEB 82-01, 83-07, 83-06, 87-02, and 88-05; IN 89-56, 89-70, 91-09, 92-68, 95-12, and 2008-04.

Commercial Grade Dedication Issues

IN 89-14, 89-59, 90-17, 91-21, and 2011-01

Design and Construction Issues

IEB 79-02, 79-04, 79-07, 79-14, IN 90-17, 95-09, 2001-14, 2007-04

Welding and NDE Issues

IN 95-45 and 2010-08

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

AWS D1.6, Structural Welding Code – Stainless 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.

NRC Publications

U.S. Nuclear Regulatory Commission, Regulatory Guides 1.99, Anchoring Components and Structural Supports in Concrete, November, 2003.

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).