Quality Assurance Manual for Moment-Resisting Steel Frame Construction

Program to Reduce the Earthquake Hazards of Steel Moment Frame Structures

50% DRAFT

Working Draft

This document has been produced as a preliminary working draft as part of the SAC Joint Venture's project to develop practice guidelines for design, evaluation, repair, and retrofit of moment-resisting steel frame structures. The purpose of this draft is to permit the project development team and prospective users of the guidelines to explore the basic data requirements and alternative methods of presenting this data in an eventual series of guideline documents. Although portions of the document must necessarily appear in the form of an actual guideline, it is not intended to serve as an interim guideline document. Information contained in this document is incomplete and in some cases, is known to be erroneous or otherwise incorrect. Information presented herein should not be used as the basis for engineering projects and decisions, nor should it be disseminated or attributed.

Quality Assurance Manual for Moment-Resisting Steel Frame Construction

Report No. SAC-XX-XX-XX

SAC Joint Venture

a partnership of:
Structural Engineers Association of California (SEAOC)
Applied Technology Council (ATC)
California Universities for Research in Earthquake Engineering (CUREe)

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January, 1999

THE SAC JOINT VENTURE

SAC is a joint venture of the Structural Engineers Association of California (SEAOC), the Applied Technology Council (ATC), and California Universities for Research in Earthquake Engineering (CUREe), formed specifically to address both immediate and long-term needs related to solving performance problems with welded steel moment frame connections discovered following the 1994 Northridge earthquake. SEAOC is a professional organization composed of more than 3,000 practicing structural engineers in California. The volunteer efforts of SEAOC's members on various technical committees have been instrumental in the development of the earthquake design provisions contained in the *Uniform Building Code* as well as the *National Earthquake Hazards Reduction Program (NEHRP) Provisions for Seismic Regulations for New Buildings and other Structures*. The Applied Technology Council is a non-profit organization founded specifically to perform problem-focused research related to structural engineering and to bridge the gap between civil engineering research and engineering practice. It has developed a number of publications of national significance including ATC 3-06, which serves as the basis for the *NEHRP Recommended Provisions*. CUREe is a nonprofit organization formed to promote and conduct research and educational activities related to earthquake hazard mitigation. CUREe's eight institutional members are: the California Institute of Technology, Stanford University, the University of California at Berkeley, the University of California at Davis, the University of California at Irvine, the University of California at Los Angeles, the University of California at San Diego, and the University of Southern California. This collection of university earthquake research laboratory, library, computer and faculty resources is among the most extensive in the United States. The SAC Joint Venture allows these three organizations to combine their extensive and unique resources, augmented by subcontractor universities and organizations from around the nation, into an integrated team of practitioners and researchers, uniquely qualified to solve problems related to the seismic performance of steel moment frame structures.

DISCLAIMER

The purpose of this document is to provide practicing engineers and building officials with a resource document for controlling the quality of construction of moment-resisting steel frame structures so that they may more reliably resist the effects of earthquakes. The recommendations were developed by practicing engineers based on professional judgment and experience and a program of laboratory, field and analytical research. **No warranty is offered with regard to the recommendations contained herein, either by the Federal Emergency Management Agency, the SAC Joint Venture, the individual joint venture partners, their directors, members or employees. These organizations and their employees do not assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any of the information, products or processes included in this publication. The reader is cautioned to carefully review the material presented herein and exercise independent judgment as to its suitability for application to specific engineering projects.** These guidelines have been prepared by the SAC Joint Venture with funding provided by the Federal Emergency Management Agency, under contract number EMW-95-C-4770.

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1. INTRODUCTION

1.1 Purpose

The purpose of these *Quality Assurance Guidelines for Moment-Resisting Steel Frame Construction* is to provide engineers, contractors, inspection agencies and building officials with guidance for appropriate construction quality control and quality assurance measures for application to the construction, upgrade or repair of moment-resisting steel frames. It is one of a series of publications prepared by the SAC Joint Venture addressing the issue of the seismic performance of moment-resisting steel frame structures. Companion publications include:

- *Seismic Design Criteria for New Moment-Resisting Steel Frame Construction* - These guidelines provide recommended design criteria and recommendations for new buildings incorporating moment-resisting steel frame construction intended to provide for construction capable of reliably meeting alternative seismic performance objectives.

- *Post-earthquake Evaluation and Repair Criteria for Welded Steel Moment-Resisting Frame Construction* - These guidelines provide recommendations for: performing post-earthquake inspections to detect damage in steel frame structures, evaluating the damaged structures to determine their safety in the post-earthquake environment and repairing damaged structures.

- *Seismic Evaluation and Upgrade Criteria for Existing Welded Steel Moment-Resisting Frame Construction* - These guidelines provide recommendations for methods to evaluate the probable performance of existing steel frame structures in future earthquakes and to retrofit these structures for improved performance.

1.2 Intent

These guidelines are primarily intended for four different groups of potential users:

a) Engineers engaged in the design of new steel frame structures or the alteration or upgrade of existing steel frame structures.

b) Regulators and building departments responsible for ensuring the public safety through adoption and enforcement of reliable building design and construction codes and practices.

c) Contractors, fabricators and erectors, responsible for constructing steel frame structures to the standards specified by the designers and as required by the building codes.

d) Testing and inspection agencies responsible for monitoring and reporting on the quality of steel frame construction.

The fundamental goal of the information presented in these guidelines is to assist the design and construction communities to develop structures capable of reliable seismic performance.

1.3 Background

Following the January 17, 1994 Northridge, California Earthquake, a number of steel buildings with welded steel moment-resisting frames (WSMF) were found to have experienced beam-to-column connection fractures. The damaged structures cover a wide range of heights ranging from one story to 26 stories; and a wide range of ages spanning from buildings as old as 30 years of age to structures just being erected at the time of the earthquake. The damaged structures were spread over a large geographical area, including sites that experienced only moderate levels of ground shaking. Although relatively few such buildings were located on sites that experienced the strongest ground shaking, damage to buildings located on such sites was extensive. Discovery of unanticipated brittle fractures of framing connections, often with little associated architectural damage to the buildings, was alarming. The discovery also caused some concern that similar, but undiscovered damage may have occurred in other buildings affected by past earthquakes. Later investigations actually confirmed such damage in buildings affected by the 1992 Landers Big Bear and 1989 Loma Prieta earthquakes.

WSMF construction is commonly used throughout the United States and the world, particularly for mid- and high-rise construction. Prior to the Northridge earthquake, this type of construction was commonly considered to be very ductile and essentially invulnerable to damage that would significantly degrade structural capacity, due to the fact that severe damage to such structures had rarely been reported in past earthquakes and there was no record of earthquake-induced collapse of such buildings. The discovery of brittle fracture damage in a number of buildings affected by the Northridge Earthquake called for re-examination of this premise. In general, WSMF buildings in the Northridge Earthquake met the basic intent of the building codes, to protect life safety. However, the structures did not behave as anticipated and significant economic losses occurred as a result of the connection damage. These losses included direct costs associated with the investigation and repair of this damage as well as indirect losses relating to the temporary, and in some cases, long term loss of use of space within damaged structures.

WSMF buildings are designed to resist earthquake ground shaking, based on the assumption that they are capable of extensive yielding and plastic deformation, without loss of strength. The intended plastic deformation consists of plastic rotations developing within the beams, at their connections to the columns, and is theoretically capable of resulting in benign dissipation of the earthquake energy delivered to the building. Damage is expected to consist of moderate yielding and localized buckling of the steel elements, not brittle fractures. Based on this presumed behavior, building codes permit WSMF structures to be designed with a fraction of the strength that would be required to respond to design level earthquake ground shaking in an elastic manner.

Observation of damage sustained by buildings in the Northridge Earthquake indicates that contrary to the intended behavior, in many cases brittle fractures initiated within the connections at very low levels of plastic demand, and in some cases, while the structures remained elastic. Typically, but not always, fractures initiated at, or near, the complete joint penetration (CJP) weld between the beam bottom flange and column flange (Figure 1-1). Once initiated, these fractures progressed along a number of different paths, depending on the individual joint conditions.

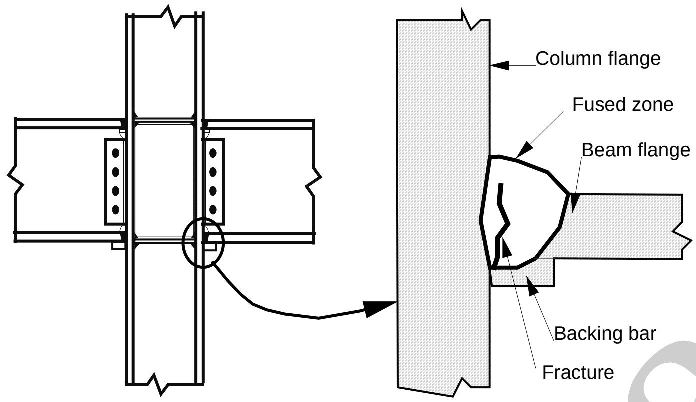
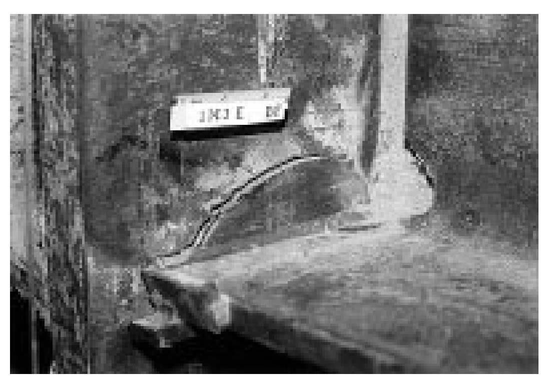


Figure 1-1 - Common Zone of Fracture Initiation in Beam -Column Connection

In some cases, the fractures progressed completely through the thickness of the weld, and if fire protective finishes were removed, the fractures were evident as a crack through exposed faces of the weld, or the metal just behind the weld (Figure 1-2a). Other fracture patterns also developed. In some cases, the fracture developed into a crack of the column flange material behind the CJP weld (Figure 1-2b). In these cases, a portion of the column flange remained bonded to the beam flange, but pulled free from the remainder of the column. This fracture pattern has sometimes been termed a “divot” or “nugget” failure.

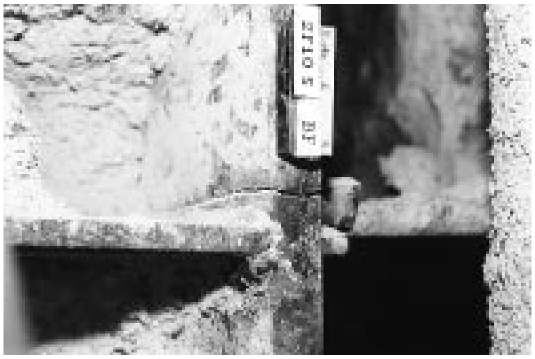
A number of fractures progressed completely through the column flange, along a near horizontal plane that aligns approximately with the beam lower flange (Figure 1-3a). In some cases, these fractures extended into the column web and progressed across the panel zone Figure (1-3b). Investigators have reported some instances where columns fractured entirely across the section.

a. Fracture at Fused Zone



b. Column Flange “Divot” Fracture

Figure 1-2 - Fractures of Beam to Column Joints


a. Fractures through Column Flange

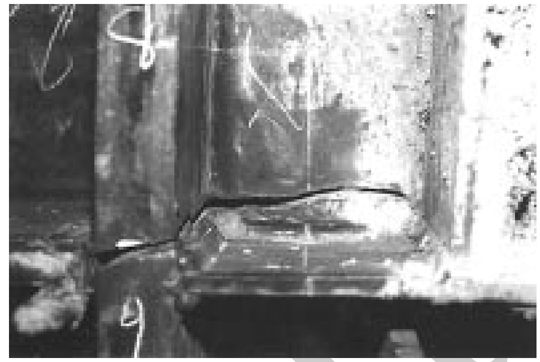

b. Fracture Progresses into Column Web

Figure 1-3 - Column Fractures

Once such fractures have occurred, the beam - column connection has experienced a significant loss of flexural rigidity and strength to resist loads that tend to open the crack. Residual flexural strength and rigidity must be developed through a couple consisting of forces transmitted through the remaining top flange connection and the web bolts. However, in providing this residual strength and stiffness, the bolted web connections can themselves be subject to failures, consisting of fracturing of the welds of the shear plate to the column, fracturing of supplemental welds to the beam web or fracturing through the weak section of shear plate aligning with the bolt holes (Figure 1-4).

Figure 1-4 - Vertical Fracture through Beam Shear Plate Connection

Despite the obvious local strength impairment resulting from these fractures, many damaged buildings did not display overt signs of structural damage, such as permanent drifts, or damage to architectural elements, making reliable post-earthquake damage evaluations difficult. Until news of the discovery of connection fractures in some buildings began to spread through the engineering community, it was relatively common for engineers to perform cursory post-earthquake evaluations of WSMF buildings and declare that they were undamaged. Unless a building exhibits overt signs of damage, such as visible permanent inter-story-drifts, in order to reliably determine if a building has sustained connection damage it is often necessary to remove architectural finishes and fireproofing and perform detailed inspections of the connections. Even if no damage is found, this is a costly process. Repair of damaged connections is even more costly. At least one WSMF buildings sustained so much connection damage that it was deemed more practical to demolish the structure rather than to repair it.

In response to concerns raised by this damage, the Federal Emergency Management Agency (FEMA) entered into a cooperative agreement with the SAC Joint Venture to perform problem-focused study of the seismic performance of welded steel moment connections and to develop recommendations for professional practice. Specifically, these recommendations were intended to address the inspection of earthquake affected buildings to determine if they had sustained significant damage; the repair of damaged buildings; the upgrade of existing buildings to improve their probable future performance; and the design of new structures to provide reliable seismic performance.

During the first half of 1995, an intensive program of research was conducted to more definitively explore the pertinent issues. This research included literature surveys, data collection on affected structures, statistical evaluation of the collected data, analytical studies of damaged and undamaged buildings and laboratory testing of a series of full-scale beam-column assemblies representing typical pre-Northridge design and construction practice as well as various repair, upgrade and alternative design details. The findings of these tasks (SAC 1995c, SAC 1995d, SAC 1995e, SAC 1995f, SAC 1995g, SAC 1996) formed the basis for the development of FEMA 267 - *Interim Guidelines: Evaluation, Repair, Modification, and Design of Welded Steel*

Moment Frame Structures (SAC, 1995b), which was published in August, 1995. FEMA 267 provided the first definitive, albeit interim, recommendations for practice, following the discovery of connection damage in the Northridge earthquake.

In the time since the publication of *FEMA-267*, SAC has continued to perform problem-focused study of the performance of moment resisting steel frames and connections of various configurations. This work has included detailed analytical evaluations of buildings and connections, parametric studies into the effects on connection performance of connection configuration, base and weld metal strength, toughness and ductility, as well as additional large scale testing of connection assemblies. As a result of these studies, as well as independent research conducted by others, it is now known that a large number of factors contributed to the damage sustained by steel frame buildings in the Northridge earthquake. These included:

- design practice that favored the use of relatively few frame bays to resist lateral seismic demands, resulting in much larger member and connection geometries than had previously been tested;
- standard detailing practice which resulted in large inelastic demands at the beam to column connections;
- detailing practice that often resulted in large stress concentrations in the beam-column connection, as well as inherent stress risers and notches in zones of high stress;
- the common use of welding procedures that resulted in deposition of low toughness weld metal in the critical beam flange to column flange joints;
- relatively poor levels of quality control and assurance in the construction process, resulting in welded joints that did not conform to the applicable quality standards;
- excessively weak and flexible column panel zones that resulted in large secondary stresses in the beam flange to column flange joints;
- large increases in the material strength of rolled shape members relative to specified values;

1.4 Application

This publication supersedes the quality assurance guidelines contained in FEMA-267, *Interim Guidelines: Evaluation, Repair, Modification and Design of Welded Steel Moment Frame Structures*, and the *Interim Guidelines Advisory*, FEMA-267a. It is intended to be used in coordination with and in supplement to the locally applicable building code and those national standards referenced by the building code. Building codes are living documents and are revised on a periodic basis. This document has been prepared based on the provisions contained in the *1997 NEHRP Recommended Provisions for the Regulation of New Buildings and Other Structures* (BSSC, 1997), the 1997 *AISC Seismic Specification* (AISC, 1997) and the 1996 *AWS*

D1.1 Structural Welding Code - Steel, as it is anticipated that these documents will form the basis for the 2000 edition of the *International Building Code*. Users are cautioned to carefully consider any differences between the aforementioned documents and those actually enforced by the building department having jurisdiction for a specific project and to adjust the recommendations contained in these guidelines, accordingly.

1.5 The SAC Joint Venture

SAC is a joint venture of the Structural Engineers Association of California (SEAOC), the Applied Technology Council (ATC), and California Universities for Research in Earthquake Engineering (CUREe), formed specifically to address both immediate and long-term needs related to solving the problem of the welded steel moment frame (WSMF) connection. SEAOC is a professional organization comprised of more than 3,000 practicing structural engineers in California. The volunteer efforts of SEAOC's members on various technical committees have been instrumental in the development of the earthquake design provisions contained in the *Uniform Building Code* as well as the *National Earthquake Hazards Reduction Program (NEHRP) Recommended Provisions for Seismic Regulations for New Buildings*. The Applied Technology Council is a non-profit organization founded specifically to perform problem-focused research related to structural engineering and to bridge the gap between civil engineering research and engineering practice. It has developed a number of publications of national significance including ATC 3-06, which served as the basis for the *NEHRP Recommended Provisions*. CUREe's eight institutional members are: the University of California at Berkeley, the California Institute of Technology, the University of California at Davis, the University of California at Irvine, the University of California at Los Angeles, the University of California at San Diego, the University of Southern California, and Stanford University. This collection of university earthquake research laboratory, library, computer and faculty resources is the most extensive in the United States. The SAC Joint Venture allows these three organizations to combine their extensive and unique resources, augmented by subcontractor universities and organizations from around the nation, into an integrated team of practitioners and researchers, uniquely qualified to solve problems in earthquake engineering.

The SAC Joint Venture developed a two phase program to solve the problem posed by the discovery of fractured steel moment connections following the Northridge Earthquake. Phase 1 of this program was intended to provide guidelines for the immediate post-Northridge problems of identifying damage in affected buildings and repairing this damage. In addition, Phase 1 included dissemination of the available design information to the professional community. It included convocation of a series of workshops and symposiums to define the problem; development and publication of a series of Design Advisories (SAC-1994-1, SAC-1994-2, SAC-1995); limited statistical data collection, analytical evaluation of buildings and laboratory research; and the preparation of the *Interim Guidelines: Evaluation, Repair, Modification and Design of Welded Steel Moment Frame Structures, FEMA-267*. The Phase 2 project was comprised of a longer term program of research and investigation to more carefully define the conditions which lead to the premature connection fractures and to develop sound guidelines for seismic design and detailing of improved or alternative moment resisting frame systems for new construction, as well as reliable retrofitting concepts for existing undamaged WSMF structures. Detailed summaries of the technical information that forms a basis for these guidelines are published in a separate series of State-of-Art reports (SAC, 1999a), (SAC, 1999b), (SAC, 1999c), (SAC, 1999d), and (SAC, 1999a).

1.6 Sponsors

Funding for Phases I and II of the SAC Steel Program was principally provided by the Federal Emergency Management Agency, with ten percent of the Phase I program funded by the State of California, Office of Emergency Services. Substantial additional co-funding, in the form of donated materials, services, and data has been provided by a number of individual consulting engineers, inspectors, researchers, fabricators, materials suppliers and industry groups. Special efforts have been made to maintain a liaison with the engineering profession, researchers, the steel industry, fabricators, code writing organizations and model code groups, building officials, insurance and risk-management groups and federal and state agencies active in earthquake hazard mitigation efforts. SAC wishes to acknowledge the support and participation of each of the above groups, organizations and individuals.

2. General

2.1 Scope

The purpose of these guidelines is to provide information relevant to the inspection of steel-framed building structures, particularly moment-resisting steel frames in regions subject to potential damaging earthquake ground motions. Included are discussions on:

- the various terms used regarding inspection functions (Chapter 2)
- the duties of the Engineer relative to control of the quality of steel, welded construction and bolted construction (Chapter 3)
- recommended Contractor (fabricator or erector) qualifications and duties relative to control of the quality of steel, welded construction and bolted construction (Chapter 4)
- recommended inspection and testing agency qualifications and duties as well as the qualifications and duties of individual inspection and testing personnel (Chapter 5)

2.2 Definitions

2.2.1 Quality Requirements

The Quality Requirements for steel frame construction are the set of material and workmanship standards which the finished construction must meet, as well as the set of procedures which are to be followed to confirm that these requirements are complied with. The Engineer is principally responsible for defining and specifying the quality requirements that apply to a project. This is typically done through reference to building code requirements and approved national standards, and may be supplemented by individual project specifications.

2.2.2 Quality Control

Quality Control includes those actions taken by the Contractor to assure that the materials and workmanship of structural steel construction meet the Quality Requirements.

Quality Control includes actions taken during fabrication / erection inspection and testing, and is the responsibility of the Contractor, unless otherwise provided for in the Contract Documents. Fabrication / erection inspection includes routine welding inspection items such as personnel control, materials control, dimensional control, preheat measurement, monitoring of welding procedures, visual inspection and nondestructive testing as specified.

Quality control varies considerably between shop and field operations, with less QC for field work and a higher reliance upon Quality Assurance.

2.2.3 Quality Control Program

The Quality Control (QC) program is a written statement, prepared by the Contractor, of all measures that will be taken to assure that construction conforms to the applicable standards. Key parts of the Quality Control program should include assuring that all parties understand what is to be constructed and the standards that apply. The Quality Control program should include ongoing efforts to monitor the effectiveness of the program.

2.2.4 Quality Assurance

Quality Assurance (QA) consists of those inspection services performed by an agency or firm other than the Contractor. QA is performed at the prerogative of the Owner and may be mandated by the Building Code. QA includes monitoring the performance of the Contractor in implementing their QC program, and assuring that designated QC functions are performed properly and on a routine basis. QA also includes performance of specific inspection tasks that may also be included in the Contractor's QC program to ensure compliance, including the performance of nondestructive testing.

2.2.5 Special Inspection

Special Inspection is a Quality Assurance activity mandated by the building code. The *Uniform Building Code* (*UBC*) requires Special Inspection but does not define it. The *National Building Code* (*NBC*) and the draft *International Building Code* (*IBC*) define Special Inspection as "inspection as herein required of the installation, fabrication, erection or placement of components and connections requiring special expertise to ensure adequacy." The *Standard Building Code* contains no provisions regarding Special Inspection. Special Inspection could best be defined as overall inspection to ensure compliance with the building code. The duty of a Special Inspector is as defined in Section 17 of the UBC, IBC or NBC.

UBC, section 1701.7, waives requirements for Special Inspection when the fabricator is approved by the Building Official, based upon the adequacy and effectiveness of the fabricator's QC program. Under the approval program, the fabricator must submit a certificate of compliance. *NBC*, section 1705.2, requires that the fabricator have their fabrication procedures reviewed and approved, but Special Inspection of the fabricated items is not waived. The *IBC* waives requirements for special inspection of work performed in by a fabricator where the fabricator maintains an agreement with an approved independent inspection or quality control agency to conduct periodic in-plant inspections at the fabricators plant, at a frequency that will assure the fabricators conformance to the requirements of the inspection agency's approved quality control program.

2.2.6 Nondestructive Testing

Nondestructive testing (NDT) includes Magnetic particle Testing (MT), liquid dye Penetrant Testing (PT), Radiographic Testing (RT) and Ultrasonic Testing (UT). The purpose of NDT is to serve as a backup to Visual Inspection (VI) and to detect flaws and defects in base metals and welds that are not visible. NDT is not a replacement for an adequate program of VI, and should not be used as such. In these Guidelines, the meaning of the terms nondestructive examination (NDE) and nondestructive testing (NDT) are identical.

2.2.7 Structural Observation

Structural Observation (SO) is defined by the *UBC* in Section 202 as:

> "The visual observation of the structural system, for general conformance to the approved plans and specifications, at significant construction stages and at completion of the structural system."

SO is performed by the Engineer or the Engineer's designated representative. It does not replace or waive SI, nor does it serve the same function. *UBC* requirements for SO are contained in Section 1702. The draft *IBC* adopts the *UBC* definition of SO but does not require it.

2.2.8 Contractor

For the purposes of these guidelines, the Contractor is the firm responsible for the fabrication or erection of the structural steel framework. In many cases, one firm will be responsible for the fabrication, defined as work performed in a fabricating shop, and another firm will be responsible for erection, defined as work performed at the jobsite. Often, the fabrication and erection is under one contract, but the erection portion is sublet to an erection specialty subcontractor. When a single firm directly performs both functions, the management of each operation is often separate, and therefore the fabrication and erection operations should be evaluated as separate organizations.

3. Engineer's Responsibilities

3.1 Scope

The Engineer is responsible for establishing, in conjunction with the Owner, the Quality Requirements for the project including the standards that the construction must meet and the necessary qualifications of the Contractor, Inspection Agency or firm, and the individuals responsible for inspection and testing. The Engineer is also responsible for establishing the Quality Assurance program for the project.

3.2 Contractor QC Program

The Structural Engineer should require the submittal of the Contractor's QC program for review. The program should include the following:

a) Designation and qualifications of project QC personnel.

b) Designation and qualifications of personnel responsible for supervision of the work.

c) Contractor's written QC and procedures manual.

d) The Fabricator/Erector's NDT procedures and NDT personnel training records.

It is recommended that the Engineer attend a pre-construction meeting or series of meetings with the Owner's representative, Contractor's QC personnel, and the QA agency's personnel to plan and discuss the project requirements, fabrication procedures, erection procedures, and inspection procedures. Topics of discussion at such meeting(s) should include:

- overall scope of work for the project
- any special construction required by the contract documents
- inspection responsibilities, including the duties of welding, bolting and other fabrication/erection personnel, the Fabricator/ Erector's QC personnel, and the QA agency's personnel
- the use of witness and hold points
- any specific NDT requirements which apply to the project, particularly those exceeding Code requirements

Fitters and welding personnel should also be provided information regarding project-specific requirements, either through a meeting or by direct dissemination of the information.

3.3 Inspection Agency Qualifications

The Structural Engineer should require submittal of the Quality Assurance agency's qualifications. The submittal should include:

a) Qualifications of QA Agency's management and QA personnel designated for the project.

b) QA agency's written inspection procedures manual and operations quality control manual.

c) Qualification records for Inspector and NDT technicians designated for the project.

d) QA Agency's NDT procedures, equipment calibration records, and personnel training records.

The review of QA agency qualifications should be performed in a timely manner. Disputes over the qualification of a QA Agency should be resolved by a qualified Engineer.

It is recommended that a pre-job meeting or series of meetings be held with the Owner's representative, Fabricator/Erector's Quality Control personnel, and QA agency's personnel to plan and discuss the project, fabrication procedures, erection procedures, and inspection procedures. Topics of discussion at such meeting(s) should include:

- overall scope of work for the project
- any special construction required by the contract documents
- inspection responsibilities, including the duties of welding, bolting and other fabrication/erection personnel, the Fabricator/ Erector's QC personnel, and the QA agency's personnel
- the use of witness and hold points
- any specific NDT requirements which apply to the project, particularly those exceeding Code requirements

Inspection personnel should also be provided information regarding project-specific requirements, either through a meeting or by direct dissemination of the information.

3.4 Project Materials and Inspection Specifications

The Engineer is responsible for specification of:

- the construction materials

- fabrication, erection and installation methods and tolerances, by reference to standards supplemented as required for project-specific conditions

- Contractor submittal requirements,

- requirements for Contractor materials controls

- requirements for special materials inspection requirements beyond standard practice as designated in the ASTM or AWS requirements, and acceptance criteria,

as indicated in the following Sections 3.5 through 3.7.

3.5 Structural Steels

3.5.1 Specification of Material

In the construction documents, the Engineer should specify the ASTM specification and grade of steel used for all structural steel elements of the building. Any Supplementary Requirements to the ASTM steel specifications, including identification of the members of the steel frame subjected to such requirements, should be clearly defined in the construction documents. Examples of Supplementary Requirements contained within ASTM Specifications include: Charpy V-Notch Impact Test, Ultrasonic Examination, Maximum Tensile Strength, Maximum Carbon Equivalent for Weldability, and Fine Austenitic Grain Size. Any other special requirements for the structural steel material regarding testing, properties, or chemistry should also be defined.

3.5.2 Submittals

The Engineer should establish requirements for the submittal of certified mill test reports for all main members. Such members include beams, girders, columns and bracing elements. Submittal of test reports for connection materials such as clip angles, single plate framing connections (shear tabs), gusset plates, beam web stiffeners, etc. need not be submitted. However, mill test reports for connection material used in moment connections, including web doubler plates and stiffeners (continuity plates) should be included.

3.5.3 Materials Control

The Engineer should establish requirements for fabrication materials control, if control beyond the grade of steel is required. Such materials control requirements may include traceability to mill heat, through the shop fit-up operation, of main steel members that are part of the lateral load resistance framing (moment-connected beams, girders and columns). When required, such heat numbers should be noted on the piece near the piece mark, and this information transferred to as-built shop drawings or a fabrication log. Where there are multiple pieces with the same piece mark, it is not necessary to identify the completed individual pieces by heat number. Following QA inspection and acceptance of the fabricated member, it is no longer necessary to maintain identification by heat number.

3.5.4 Inspection

QA mill inspection, prefabrication steel inspection, testing, or verification of chemistry or mechanical properties, if required, must be designated by the Engineer in the construction documents.

3.6 Fabrication and Erection

The engineer should require submittal of erection and shop drawings for the work. The erection drawings should identify piece marks for each fabricated element to be incorporated in the work, keyed back to the individual shop drawings. Any special sequence or erection instructions should be included on the erection drawings. Shop drawings should provide sufficient information to allow fabrication to be performed. The engineer should review the shop and erection drawings to assure that the overall structural configuration and detailing requirements conform with the design intent.

3.7 Welding

3.7.1 Specification of Material

All electrodes, fluxes and shielding gases shall conform to the latest A5 specifications of the American Welding Society.

In the construction documents, the Engineer should specify the appropriate AWS specifications for welding materials to be used for all elements of the building. Any special requirements to the AWS A5 specifications, including identification of the joints of the steel frame subjected to such requirements, should be clearly defined in the construction documents. Such requirements may include toughness and diffusible hydrogen levels. Where toughness is required in designated joints, the Engineer shall specify the minimum toughness value and testing temperature.

3.7.2 List of Required Submittals / Certifications

The Engineer should prepare a list of required certifications of welding materials, including electrodes, fluxes and shielding gases. Certifications for each product used should be submitted by the Contractor, with a copy provided to the appropriate Inspector for review. It should be noted that certifications are for compliance with the appropriate AWS A5 Specification, and are not a material test report taken from the specific lot of material being used. Such lot-specific tests are not required.

The Engineer should require submittal of Welding Procedure Specifications (WPS) and/or Procedure Qualification Reports (PQRs) prepared by the Fabricator/Erector or designated source, including results of CVN testing, where toughness control is required.

3.7.3 Materials Controls

Special welding materials control requirements such as lot traceability is not required. Manufacturer certifications document the overall quality of all welding material supplied, and variation from lot to lot is not significant. Materials control to verify that welding materials requiring toughness are used where required is appropriate. Welding materials storage controls, such as with SMAW low-hydrogen electrodes requiring rod storage ovens and having limited atmospheric exposure times, must be as provided in AWS D1.1 Section 5. Any additional requirements must be specified in the Contract Documents.

3.7.4 Welding Procedure Specifications

The Engineer should require the submittal of Welding Procedure Specifications (WPSs) for each weld to be made on the project. For shop welds, the Fabricator is responsible for developing and supplying the WPSs. For field welds, the Erector is responsible for developing and supplying the WPSs. WPSs must also be distributed to the Inspector responsible for welding inspection. The Engineer should review and approve the WPSs for general suitability and adequacy, but need not take responsibility for the suitability or quality of the welds made using such procedures. Such responsibility remains with the Contractor responsible for the welding. When Procedure Qualification Records (PQRs) are needed for non-prequalified WPSs, they shall also be submitted for review by the Engineer.

AISC Seismic Provisions for Structural Steel Buildings, section 7.3a states:

> "Welding shall be performed in accordance with a Welding procedure Specification (WPS) as required in AWS D1.1 and approved by the Engineer of Record."

3.7.5 List of Required Inspections

The Engineer should prepare a list of all inspections required and designate the party responsible for each task. Such inspection may be provided by the Contractor (Fabricator or Erector), by the Special Inspector, by the Welding Inspector, or by the Nondestructive Testing technician.

The Engineer should specify any required NDT, other than visual, by type or location of joint. The extent of NDT, whether full length, partial length, or spot testing should be stated.

> *Commentary: The basic code requirements for structural welding of steel structures are contained in AWS D1.1 - Structural Welding Code - Steel. AWS D1.1 uses the term "Fabrication/Erection Inspection" synonymously with the classical "Quality Control" function. The term "Verification Inspection" is used to describe the classical "Quality Assurance" function. AWS D1.1 requires inspection for many items in Section 6, Part A, but does not specify whether the inspection is performed as either QC or QA. Such distinction must be provided in*

the Contract Documents by the Engineer.

3.7.6 Weld Acceptance Criteria

The Engineer should establish, in writing, the level of welding quality required for the project. Such requirements may be as required under AWS D1.1, or other suitable criteria as suggested in the technical literature. The use of alternate acceptance criteria is permitted by AWS D1.1, Section 6.8.

3.8 Bolting

3.8.1 Specification of Materials

The Engineer should specify the materials for bolted connections. Production and inspection for all fastener materials should be specified to conform to the latest edition of the ASTM Specifications. Bolts shall meet ASTM A325, A490, F1852 (twist-off bolt), or other bolt specification as permitted for use in the AISC Specification. Nuts shall meet either ASTM A563 or A194 specifications. Washers shall meet the ASTM F436 specification. Direct tension indicators, if used, shall meet the ASTM F959 specification.

3.8.2 List of Required Submittals / Certifications

The Engineer should prepare a list of required certifications of bolting materials, including bolts, nuts and washers. Certification of fastener materials by the fastener component manufacturer is a requirement of the ASTM Specifications. Certifications for each product used should be submitted by the Contractor, with a copy provided to the appropriate Inspector for review. Certifications should be provided for each production lot of fastener component, with the exception of shipping lot certification permitted for A490 bolts. The acceptance of shipping lot certifications is discouraged.

3.8.3 Materials Controls

The Engineer should establish requirements for fastener materials control, if control beyond type or lot is required. The Research Council on Structural Connections (RCSC) Specifications require pre-installation testing by lot, prior to installation in the work, to verify the material suitability and installation procedures. Upon installation, no lot control or traceability is required for the turn-of-nut, twist-off bolt, and direct tension installation methods. For the calibrated wrench method, lot control is required to maintain consistency of installation using this torque control method. Upon completion of installation, no records need be maintained regarding source or lot of fastener materials.

3.8.4 Bolting Procedures

The Engineer should require the submittal of written procedures for the pre-installation testing, installation and pretensioning of high-strength bolts on the project. The procedures must meet the requirements of the RCSC Specifications. Procedures need be submitted only for the method(s) of installation being used by the Fabricator / Erector, which may include turn-of-nut, calibrated wrench, twist-off bolt, or direct tension indicator. Procedures should include both installation to the snug tight condition and pretensioned installation. Bolting procedures must also be distributed to the Inspector responsible for bolting inspection.

3.8.5 List of Required Inspections

The Engineer should prepare a list of all bolting inspections required and designate the party responsible. Such inspection may be provided by the Contractor (Fabricator or Erector), by the Special Inspector, or by the Bolting Inspector.

3.8.6 Inspection Procedures

The Engineer should require the submittal of written inspection procedures for bolted installations. Such procedures must meet the requirements of the RCSC Specifications. Inspection procedures should be written specifically for the installation and pretensioning method(s) to be used, i.e. turn-of-nut, calibrated wrench, twist-off bolt, or direct tension indicator. Written procedures should also be prepared for the arbitration of disputes, to be used when a question arises regarding the pretension of previously installed fasteners.

4. Contractor Qualification and Responsibilities

4.1 Scope

In order to establish the necessary level of Quality Control (QC) and Quality Assurance (QA) for a particular project it is necessary to establish the level of experience and competence of the Contractor. The "Contractor" in this section is the steel fabricator responsible for the shop fabrication of the structural steel, and/or the steel erector, responsible for all field erection and field welding. The general contractor or construction manager is not the "Contractor" in this section, unless they are performing some or all of the duties of fabricator or erector.

The Owner carries responsibility selection of the Contractor. The Owner must ensure that the Contractor has established and put into practice an adequate Quality Control program. The Owner is responsible for the Quality Assurance program. The use of "certified" or "qualified" fabrication shops, in lieu of requiring independent Quality Assurance provided by the Owner, is not recommended. However, a fabrication shop that is certified or qualified by a recognized program, such as the AISC Quality Certification Program, does provide a level of assurance that the fabricator has the capability of providing good fabrication performance.

The purpose of a QA program is to provide an oversight to the Contractor's QC program. This may range from simple records and report reviews to a full testing and inspection program, depending upon the effectiveness of the Fabricator/Erector's QC program, and the requirements of the Building Code. Often this cannot be established until the Contractor is selected.

The Owner is responsible for establishing the Quality Assurance program. Elements in an acceptable Quality Assurance program should conform to those required by the Building Code. Because most owners have little expertise or knowledge related to construction, this often means that the Engineer must advise the Owner, and, in many cases, establish the QA program.

4.2 Certification Programs

In determining the adequacy of a Contractor's qualifications, the Owner may evaluate whether the Contractor has been certified under one or more of the programs indicated in this section.

4.2.1 AISC Quality Certification

The American Institute of Steel Construction's Quality Certification Program was instituted to develop a system under which Owners, Engineers and Building Officials could evaluate the quality of steel fabricators. A voluntary program, steel fabricators are evaluated on the basis of their overall quality control program, judging the general management, engineering and drafting, purchasing, shop operations and quality control functions of the individual plant. Multi-plant fabricating companies are certified on a plant-by-plant basis.

The AISC Quality Certification Program is used to determine if the plant “has the personnel, organization, experience, procedures, knowledge, equipment, capability and commitment to produce fabricated steel of the required quality for a given category of structural steel work.”

There are two categories of certification for structural steel buildings, plus two categories for steel bridge structures. Conventional Steel Building Structures, previously known as Category I, include:

- small public service and institutional buildings (schools, etc.)
- shopping centers
- low rise truss and beam / column structures
- light manufacturing plants
- miscellaneous and ornamental iron fabricated to AISC Specifications
- warehouses
- sign structures

Complex Steel Building Structures, previously known as Category II, include:

- large public service and institutional buildings
- high rise buildings
- stadia
- auditoriums
- heavy manufacturing plants
- powerhouses (fossil, non-nuclear)
- metal producing / rolling facilities
- crane girders
- bunkers and bins
- chemical processing plants
- petroleum processing plants

Another classification of AISC Quality Certification, Category MB - Metal Building Systems, applies to pre-engineered metal building systems. This category of certification includes a review of the design procedures used by the manufacturer of the building system in designing the structure, as well as their fabrication capabilities and systems.

Fabricating plants certified for Complex Steel Buildings are automatically certified for Conventional Steel Building work.

4.2.2 AISC Erector Certification

The American Institute of Steel Construction's Erector Certification Program was instituted to develop a system under which the construction industry could evaluate the quality of steel erectors. A voluntary program, steel erectors are evaluated on the basis of their overall quality control program, judging the management and operations of the erector.

The AISC Erector Certification Program is used to determine if the plant "has the personnel, organization, experience, procedures, knowledge, equipment, capability and commitment to erect fabricated steel of the required quality for a given category of structural steelwork."

There are two categories of certification for structural steel erectors. A Certified Steel Erector

- schools
- shopping centers
- light manufacturing plants
- warehouses
- low rise beam and column structures
- light truss structures
- steel-framed buildings up to ten (10) stories in height

A Certified Advanced Steel Erector may provide services on structures including, but not limited to:

- large public and institutional buildings
- heavy manufacturing plants
- bunkers and bins
- powerhouses

- major industrial facilities
- high rise buildings greater than ten (10) stories
- repair and rehabilitation of existing steel structures

4.2.3 Building Code Evaluation Services

ICBO Evaluation Services, Inc. and BOCA Evaluation Services, Inc. provide evaluations of various manufacturers and products. Under ICBO ES, steel fabricators are listed as Fabricators of Prefabricated Buildings and Components (064). BOCA listings for steel fabricators and steel fabrications are contained in Division 5, but no specific category exists for structural steel fabricators, nor are steel fabricators listed.

4.2.4 Alternatives to Certification

4.2.4.1 ISO 9000

Alternatives to certification programs such as AISC or ICBO ES, as described above, include the use of ISO 9000 or related credentials of the steel fabricator. A review of the fabricator's program and the audits conducted is advisable. Few fabricators have presently sought such ISO certification.

4.2.4.2 Jurisdiction Evaluation

Some local jurisdictions, such as the City of Los Angeles and the City of Houston, have programs in place to evaluate fabricators. The Owner should review the adequacy of such programs to qualify the Contractor for the type of work being undertaken by the fabricator.

4.2.4.3 Individual Evaluation

The Owner may evaluate the fabricator and erector individually to ascertain the level of experience and skill of the fabricator, and to evaluate their quality control program. Such evaluations should be undertaken by personnel experienced in the field of structural fabrication, including materials control, welding, and bolting.

4.3 Contractor's QC Program

The Contractor is responsible for establishing and implementing a suitable QC Program for in-process quality control of the work.

The Contractor's QC function should be isolated from the production department, and the QC Manager should report directly to a high level company officer to avoid conflicts of interest with production.

The Contractor's QC Program should be in writing, enabling others to make an effective evaluation of the adequacy of the Program. The Contractor should also make periodic, at least annual, reviews of their QC Program to verify its adequacy and to determine that the Program is being followed at all levels of the Contractor's operations.

4.3.1 Structural Steel QC Program

Important aspects of a Fabricator's QC program for materials control should include as a minimum:

- written procedures for inspection of steel materials upon receipt, including verification of heat numbers and mill test reports.
- written, functioning system of materials control by grade, and also by heat number if required.
- Mill test reports for primary structural members must be kept on file.

4.3.2 Welding QC Program

Important aspects of a Contractor's QC program for welding should include as a minimum:

- Welders must be qualified for the work in accordance with AWS D1.1, Section 5, Part C.
- Suitable Welding Procedure Specifications (WPSs) must be provided for all welding to be performed, and must be available to welding personnel at the place of work
- Welding equipment must be adequate and functioning properly, and calibrated for accuracy within the past year.
- Welding materials storage equipment such as rod ovens and flux ovens must be available and functional, if required by the process, filler metal or flux.
- Welding personnel should be knowledgeable regarding the use of WPSs, basic workmanship provisions, and in the use of weld gages and temperature measurement devices such as temperature indicating crayons.
- Welding inspectors must be qualified in accordance with AWS D1.1, Section 6.1.4 to perform QC inspection.
- If not provided by the fabricator's QC personnel, outside NDT services must be available to the fabricator on an as-needed basis.

4.3.3 Bolting QC Program

Important aspects of a Contractor's QC program for bolting should include as a minimum:

- A proper protected storage area is provided for all fasteners.
- A suitable materials control system, including lot control, is in use.
- A bolt calibration device, calibrated within the past year, is available.
- Written bolting procedures are provided for the installation method(s) to be used.
- The bolting crew must be knowledgeable of bolting installation procedures.
- Bolting inspectors must be trained and knowledgeable.

4.4 Contractor's Responsibilities - Structural Steel

The Fabricator should establish written procedures for fabrication materials control, as a minimum for steel grade identification. Such materials control requirements should, if required, include traceability to mill heat numbers, through the shop fit-up operation, of main steel members that are part of the moment framing (beams, girders and columns). Such heat numbers should be noted on the piece near the piece mark, and this information transferred to as-built shop drawings or a fabrication log. Where there are multiple pieces with the same piece mark, it is not necessary to identify the individual pieces by heat number using additional piece marks. Following QA inspection and acceptance of the fabricated member, it is no longer necessary to maintain identification by heat number.

4.4.1 Submittals

Certified mill test reports should be submitted and reviewed prior to acceptance of the fabricated item by the Inspector. These reports identify the manufacturer, size, heat number, chemistry, yield strength, and ultimate strength, plus any other properties required. These properties may include notch toughness, fine grain practice, or any other item required by the contract documents and supplied by the mill.

The Fabricator should submit certified mill test reports for all main members. Such members include beams, girders, columns and bracing elements. Test reports for connection materials such as clip angles, single plate framing connections (shear tabs), gusset plates, beam web stiffeners, etc. need not be submitted, except that mill test reports for connection material used in moment connections, including web doubler plates and stiffeners (continuity plates) should be included in the submittal. Material used by the fabricator for other connection material may be drawn from fabricator stock of known grade, provided the stock has had material test reports previously received and reviewed by the fabricator.

4.5 Contractor's Responsibilities - Welding

The Contractor should make available to the Engineer, Inspector and NDT Technician all drawings, project specifications, mill certifications, welder qualification records, WPSs and PQRs applicable to the project. The Contractor should cooperate fully with requests from inspection and testing personnel for access to the connections and joints to be inspected or tested. This includes beam and column turning in the shop, weld backing removal when required, and access platforms or scaffolding as required to perform the work safely.

The Contractor is responsible for all necessary corrections of deficiencies in materials and workmanship. The Contractor should comply with requests of the Inspector to correct deficiencies, when such corrections are required by the Engineer. The NDT Technician should be apprised of any repairs made by the Contractor. Inspections should be performed in a timely manner. Disputes should be resolved by the Engineer of Record, or by a Welding Engineer designated by the Engineer of Record.

The Contractor should require and ensure that welders meet established minimum requirements. Execution of critical welds requires skilled welders who will follow the project welding requirements. Welds executed by welders who do not satisfy the welder performance qualifications should be considered rejectable.

4.5.1 Submittals - Welding

The Contractor should submit all WPSs, welding materials manufacturer data sheets, PQRs, and welder qualification records for review by the Engineer and/or Inspector, as required. Manufacturer's certification that the welding electrodes, fluxes and shielding gases, as supplied, meet the applicable AWS A5 specification shall be submitted.

4.6 Contractor's Responsibilities - Bolting

4.6.1 Submittals - Bolting

Manufacturer's certification that all bolts, washers, nuts and other fastener components, as supplied, meet the applicable ASTM specification shall be submitted. The Contractor should also submit bolt installation procedures for review by the Engineer and/or Inspector, as appropriate.

4.7 Quality Control and Quality Assurance

4.7.1 Extent of Welding QC Inspection and NDT

In the information furnished for bidding, the Engineer should clearly identify the extent of inspection and NDT to be performed by the Contractor and by the Inspector or NDT Technician. Weld joints requiring NDT by Contract Documents shall be tested for their full length, unless partial or spot testing is specified. When partial or spot testing is specified, the location and lengths of welds or categories of weld to be tested should be clearly designated in writing in the

Contract Documents, or using NDT symbols in conjunction with the welding symbols on the design drawings. See AWS D1.1, Section 6.15.

On projects where a sliding sampling scale is used, the Inspector should keep records on each welder or welding operator. These records may be used as a basis for sampling rate reduction.

4.7.2 Extent of Bolting QC Inspection

In the information furnished for bidding, the Engineer should clearly identify the extent of inspection to be performed by the Contractor and by the Inspector or NDT Technician. Bolted joints require only verification of the quality of the holes, visual inspection by observation of the pre-installation tests and the tightening operations, and if a slip-critical joint is specified, the condition of the faying surface. The use of torque for random testing of installed bolts is discouraged.

4.7.3 Extent of Steel QC Inspection

In the information furnished for bidding, the Engineer should clearly identify the extent of inspection to be performed by the Contractor and by the Inspector or NDT Technician. Steel materials inspection is typically limited to visual inspection of the surface condition of the steel, as well as visual inspection of thermal cut surfaces for indications of laminations. Verification of the system for maintaining steel grade and heat number identification, when needed, is also important. The use of additional physical sampling and testing is discouraged.

5. Special Inspection Agency Qualifications and Responsibilities

5.1 Scope

This section defines the appropriate qualifications for organizations and individuals performing Quality Assurance (QA)of steel construction, and the responsibilities of those quality assurance firms and individuals.

When inspection or NDT is performed by the Contractor (fabricator or erector) as a part of the Quality Control (QC) function, the qualifications of the individual(s) performing such inspection or NDT should meet the same standards as the individual(s) performing QA. It is not expected that the Contractor have the same qualifications or certifications as a firm performing such work.

5.2 General

The basic code requirements for structural welding of steel structures are contained in AWS D1.1 - Structural Welding Code - Steel. AWS D1.1 uses the term "Fabrication/Erection Inspection" synonymously with the classical "Quality Control" function. The term “Verification Inspection” is used to describe the classical “Quality Assurance” function. AWS D1.1 requires inspection for many items in Section 6, Part A, but does not specify whether the inspection is performed as either QC or QA. Such distinction must be provided in the Contract Documents by the Engineer.

Fabrication/erection inspection (QC) and verification inspection (QA) and NDT should be performed concurrently whenever possible to ensure that the Contractor's QC program is meeting the requirements of the Contract Documents.

5.3 Qualification of Inspection Agencies

The firm or agency responsible for the Quality Assurance function, whether an independent testing laboratory or an individual, must be capable of performing the work, and should be evaluated and approved by the Owner, with the assistance of the Engineer, for capability to perform such functions. The Building Official may also have requirements regarding the qualification of firms or individuals who will be performing the work. The level of expertise and experience necessary to perform such functions depends upon the specific role of the inspector, as a Special Inspector, Welding Inspector, or NDT (nondestructive testing) technician.

Each agency performing welding-related Quality Assurance work should employ an individual, qualified to American Society for Nondestructive Testing (ASNT) Level III for the type of welding inspection to be performed. This individual should be responsible for the supervision of equipment calibration, inspection procedures, personnel certification, and training for the project.

5.3.1 Testing Laboratory Accreditation Programs

There are several accreditation programs available to independent testing laboratories to demonstrate, to a third party, their expertise in a particular field. Such programs include:

National Voluntary Laboratory Accreditation Program (NVLAP)- NVLAP is administered by the National Institute of Standards and Technology (NIST), and accredits public and private laboratories based upon evaluation of their technical qualifications and competence, following ISO/IEC Guide 25 and ISO 9002. Laboratories are reviewed in the following areas: accommodation and environment, calibration and test methods, certificates and reports, complaints, equipment and reference materials, handling of calibration and test items, measurement traceability and calibration, organization and management, outside support services, personnel, quality system, audit and review, records, and subcontracting. Fields of accreditation include Construction Materials Testing, and Fasteners and Metals. Fewer than 20 agencies are accredited for Construction Materials.

American Association for Laboratory Accreditation (A2LA) - A2LA is a membership organization that offers accreditation in a variety of fields, including Construction Materials and Nondestructive Testing. A2LA follows ISO/IEC Guide 25 - 1990, General Requirements for Accreditation of Laboratories, in its accreditation process. Approximately 100 offices are accredited for Construction Materials.

American Council of Independent Laboratories (ACIL) - ACIL is a membership organization of approximately 350 firms in various disciplines, operating approximately 1500 facilities.

ICBO Evaluation Services, Inc. (ICBO ES) - ICBO ES conducts evaluations and issues reports on a variety of materials and services, including Testing Laboratories (268). Specific areas of testing are listed in bi-monthly Evaluation reports listings. However, published reports for Testing Laboratories are not made available.

BOCA Evaluation Services, Inc. (BOCA-ES) - BOCA-ES conducts evaluations and issues reports on a variety of materials and services, including Testing Laboratories (Section 01410) and Inspection Services (Section 01420). Testing Laboratories are typically facilities performing product testing such as physical or fire testing. Inspection Services are typically firms providing product manufacturers with QC services, although some firms offer jobsite services.

American Welding Society (AWS) - AWS offers an accreditation program for testing laboratories that wish to conduct AWS Certified Welder Program tests. It does not evaluate inspection services beyond the scope of welding personnel testing.

The Engineer may refer to the following standards for assistance in evaluating inspection and testing agencies:

- ASTM E329 - Standard Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction

- ASTM E543 - Standard Practice for Agencies Performing Nondestructive Testing
- ASTM E548 - Standard Guide for General Criteria Used for Evaluating Laboratory Competence
- ASTM E1359 - Standard Guide for Surveying Nondestructive Testing Agencies
- ASTM E1212 - Standard Practice for Establishment and Maintenance of Quality Control Systems for Nondestructive Testing Agencies
- ASTM E994 - Standard Guide for Laboratory Accreditation Systems

5.4 Written Practice

5.4.1 Written Practice for Testing Agencies

The Testing Agency should maintain a written practice for the control and administration of inspection personnel training and qualification. The Agency's written practice should describe the training, experience and requirements for qualification of inspection personnel.

The written practice should describe the Agency's procedures for determining the acceptability of the structure in accordance with the applicable codes, standards, specifications and procedures, including general inspection, materials controls, visual welding inspection, and bolting inspection.

5.4.2 Written Practice for Nondestructive Testing Agencies

The Testing Agency should maintain a written practice for the control and administration of NDT personnel training, examination and certification. The employer's written practice should describe the training, experience and examination requirements for each level of certification. The employer's written practice should describe the responsibility of each level of certification for determining the acceptability of materials and weldments in accordance with the applicable codes, standards, specifications and procedures.

Commentary - The NDT Agency's written practice should be based upon either of two documents: ASNT Recommended Practice No. SNT-TC-1A (1996), Personnel Qualification and Certification in Nondestructive Testing; or ANSI/ASNT CP-189-95, ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel.

5.5 Qualification of Inspection Personnel

Inspectors responsible for acceptance or rejection of materials and workmanship shall be qualified to perform such inspection. The level of expertise of the individual inspector depends upon the specific inspection role assigned and the complexity of the project. Inspectors are selected by the Testing Agency responsible for the work, however, the Engineer and Building Official have the authority to verify the qualification of such inspectors.

The Inspector may use assistants who are formally designated, made aware of their assigned responsibility and the acceptance criteria, and work under the direct supervision and monitoring of a qualified Inspector.

5.5.1 Definitions

5.5.1.1 Qualification

General Welding Inspector qualifications are defined by AWS D1.1 in section 6.1.4. For nondestructive testing, ANSI/ASNT CP-189 defines the education, skills, training, knowledge, and experience required for personnel to properly perform to a specified NDT Level. ASNT SNT-TC-1A defines the demonstrated skill, demonstrated knowledge, documented training, and documented experience required for personnel to properly perform the duties of a specific job.

5.5.1.2 Certification

AWS defines certification as the act of determining, verifying, and attesting in writing to the qualification of personnel in accordance with specified requirements. Under CP-189, ASNT defines certification as written testimony that an individual has met the applicable requirements of the standard; under SNT-TC-1A, written testimony of qualification.

5.5.2 Special Inspector Qualification

The qualification of the Special Inspector must be established by the organization responsible for the Special Inspection, whether the Owner or the Owner's representative. The qualifications and selection of the Special Inspector must be approved by the Building Official, as a part of the issuance of the building permit. The Special Inspector may be either an individual or a firm. If a firm, the individuals performing the Special Inspection function should meet the minimum qualifications to perform such work as established by the Engineer, Owner, or Building Official and the testing firm.

The Engineer, Owner or Building Official may require the Special Inspector to maintain certification by an outside agency, such as ICBO/ICC, AWS, or another independent accreditation agency.

5.5.3 Welding Inspector Qualification

Visual welding inspection personnel should be qualified under AWS D1.1, Section 6.1.4. The basis of qualification should be specified by the Engineer. Acceptable qualification bases under D1.1 are:

a) Current or previous certification as an AWS Certified Welding Inspector (CWI) in accordance with the provisions of AWS QC1, *Standard for AWS Certification of Welding Inspectors*, or

b) Current or previous qualification by the Canadian Welding Bureau (CWB) to the requirements of the Canadian Standard Association (CSA) Standard W178.2, *Certification of Welding Inspectors*, or

c) An engineer or technician who, by training or experience, or both, in metals fabrication, inspection and testing, is competent to perform inspection work.

The qualification of an inspector remains in effect indefinitely, provided the inspector remains active in the inspection of welded steel fabrication, or unless there is a specific reason to question the inspector's ability.

AWS D1.1 does not recognize the AWS Certified Associate Welding Inspector as qualified to perform the work solely based upon this certification. A CAWI has passed the same accreditation examination as the CWI, but has less experience, with two years minimum experience rather than five years, in the field of welding inspection. A CAWI could be acceptable under condition "c" as listed above. The Senior Certified Welding Inspector is a new program offered by the AWS, and this recent certification option has not been included in the D1.1 code because of publication schedules. A SCWI should be considered the equivalent of a CWI.

Although AWS D1.1 allows inspector qualification without the CWI certification under AWS QC1 criteria, it is strongly recommended that the welding inspection personnel for critical welding be AWS QC1 certified (or previously certified) by experience and written examination.

All Welding Inspectors must have adequate visual acuity, documented by vision testing performed within the past three years. See AWS D1.1, Section 6.1.4.4.

5.5.4 NDT Personnel Qualification

Certification of all levels of NDT personnel is the responsibility of the employer of the NDT technician. It is strongly suggested that the certification of NDT personnel should be administered by an ASNT ACCP Certified Level III in the specific area on NDT.

Commentary: It is also possible to be "self-certified" as an ASNT Level III under the SNT-TC-1A Recommended Practice.

Nondestructive testing personnel should be qualified under the American Society for Nondestructive Testing, Inc., ANSI/ASNT CP-189, *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel*, or ASNT *Recommended Practice No. SNT-TC-1A, Personnel Qualification and Certification in Nondestructive Testing.*

Certification of NDT personnel should be based on demonstration of satisfactory qualification in accordance with Sections 6, 7 and 8 of ASNT SNT-TC-1A, as modified by the employer's written practice, or in accordance with Sections 4, 5 and 6 of ANSI/ASNT CP-189. Personnel certifications must be maintained on file by the employer and a copy should be carried by the technician.

Employers may rely upon outside training and testing for NDT personnel for certification, however, the employer should supplement such certification testing with a review of the technician's experience and skill levels. As an example, the technician may have successfully passed the Level II examination for that NDT process as administered by either the AWS or ASNT.

AWS D1.1 Section 6.14.6 requires that nondestructive testing be performed by ASNT Level II technicians, or by Level I technicians only when working under the direct supervision of a Level II.

Commentary: Inspection by a Level III technician is not recognized, as the Level III may not perform actual testing regularly enough to maintain the special skills required to set up or to conduct the tests. AWS D1.5-96 requires similar qualification, except in the case of Fracture Critical Members. Under Section 12.16.1.2, testing of fracture critical members must be done by either a qualified Level II under the supervision of a qualified Level III, or by a Level III certified by ASNT, unless the Engineer accepts other forms of qualification.

5.5.4.1 Levels of NDT Qualification

ASNT identifies four qualification levels, as defined in CP-189:

Trainee - A person who is not yet certified to any level. Trainees shall work with a certified person, under the direction of an NDT Level II or NDT Level III and shall not independently conduct any tests or write a report of test results.

NDT Level I - An NDT Level I individual shall have the skills to properly perform specific calibrations, specific NDT, and with prior written approval of the NDT Level III, perform specific interpretations and evaluations for acceptance or rejection and document the results. The NDT Level I shall be able to follow approved nondestructive testing procedures and shall receive the necessary guidance or supervision from a certified NDT Level II or NDT Level III individual.

NDT Level II - An NDT Level II individual shall have the skills and knowledge to set up and calibrate equipment, to conduct tests, and to interpret, evaluate, and document results in accordance with procedures approved by an NDT Level III. The Level II shall be thoroughly familiar with the scope and limitations of the method to which certified and should be capable of directing the work of trainees and NDT Level I personnel. The NDT Level II shall be able to organize and report nondestructive test results.

Commentary: The Level II technician may have taken written and practical tests as administered directly by either the ASNT or the AWS. Such independent testing *of the Level II technician is not required to be considered a Level II.*

NDT Level III - An NDT Level III individual shall have the skills and knowledge to establish techniques; to interpret codes, standards, and specifications; designate the particular technique to be used; and verify the accuracy of procedures. The individual shall also have general familiarity with the other NDT methods. The NDT Level III shall be capable of conducting or directing the training and examining of NDT personnel in the methods for which the NDT Level III is qualified.

Commentary: Additional provisions from SNT-TC-1A include: The NDT Level III should be responsible for the NDT operations for which qualified and assigned and should be capable of interpreting and evaluating results in terms of existing codes, standards, and specifications. The NDT Level III should have sufficient practical background in applicable materials, fabrication, and product technology to establish techniques and to assist in establishing acceptance criteria when none are otherwise available.

The Level III technician may have taken written and practical tests as administered directly by either the ASNT or the AWS. Such independent testing of the Level III technician is not required to be considered a Level III under SNT-TC-1A. Such independent testing of Level III technicians is highly recommended, and is required under CP-189.

5.5.4.2 Recertification of NDT Personnel

Under ANSI/ASNT CP-189,NDT Level I and II personnel shall be recertified by written and practical examination in accordance with Section 6. Individual certifications expire at the end of three years. NDT Level III personnel shall be recertified by the employer every five years by verifying that the individual’s ASNT NDT Level III certificate is current in each method for which recertification is sought. Should the ASNT NDT Level III certificate expire prior to the five years, the individual must retest for that certificate.

Under ASNT SNT-TC-1A, all levels of NDT Personnel shall be recertified periodically in accordance with either evidence of continuing satisfactory performance, or reexamination in those portions of the examinations in Section 8 deemed necessary by the employer's NDT Level III. The maximum (recommended) recertification intervals are three (3) years for Levels I and II, and five (5) years for Level III. The employer's written practice should include rules covering the duration of interrupted service that requires reexamination and re-certification.

5.5.4.3 Suspension of Certification

The employer should suspend an individual’s certification if:

a) the vision examination interval exceeds one year. Certification is reinstated concurrently with passing the vision examination; or

b) the individual has not performed the duties in the methods(s) for which certified during the previous twelve months; or

c) the individual's performance is determined to be deficient in the method or technique for specific documented reasons; or

d) for NDT Level III personnel, when the ASNT Level III certificate has not been renewed.

5.5.4.4 Revocation of Certification

The employer shall revoke an individual's certification when:

a) the individual has not been performed the duties in the method(s) for which certified within the past 24 months; or

b) for NDT Level III personnel, the ASNT NDT Level III certificate has been revoked; or

c) an individual's conduct is deemed by the employer to be or have been unethical or incompetent.

5.5.5 Certification Programs

5.5.5.1 ICBO Certified Special Inspector for Structural Steel and Welding

The ICBO maintains a certification program for inspectors of steel-framed structures. This program consists of a test of an inspector's knowledge of the steel and special inspection related sections of the Uniform Building Code, AISC Specification for Structural Steel Buildings, AISC Manual of Steel Construction, AWS D1.1, D1.3 and D1.4 Structural Welding Codes, AWS A2.4 Welding Symbols, and the inspector's ability to read and interpret structural steel erection drawings. No experience is required to take the test or to receive Certification.

5.5.5.2 Certified Building Official

Building Officials may elect to take certification exams relative to their respective model building code. Such exams cover the broad extent of the entire code, and may not deal with the specific provisions and inspection procedures or issues directly related to steel construction. Additional education and training relative to steel construction and inspection is generally needed.

5.5.6 Certified Welding Inspector

The American Welding Society offers certification to welding inspectors in the form of Certified Welding Inspectors, Certified Associate Welding Inspectors, and Certified Senior

Welding Inspectors. ANSI/AWS QC-1-96, *Standard for AWS Certification of Welding Inspectors*, governs the requirements and testing of such inspectors, including experience level. The CWI examination tests the inspector's knowledge of welding processes, welding procedures, welder qualification, destructive testing, nondestructive testing, terms, definitions, symbols, reports, records, safety and responsibilities. Although assumed to be competent to inspect welded construction, the AWS Certified Welding Inspector may not have the background or expertise in other areas of steel construction such as general fabrication and erection, bolted connections, steel bar joists, and metal decks, and additional education and training relative to these areas may be needed. It should also be verified that the AWS Certified Welding Inspector has tested, or is familiar with, the AWS D1.1 Structural Welding Code. It is permitted to take the AWS examinations using either the AWS D1.1 or the API 1104 codes, and welding inspection experience may be in any area of welding.

5.6 Duties of the Inspectors

5.6.1 General

Depending upon the structure of the QA and QC functions for the particular project, the role of the visual Inspector may vary considerably. Ideally, the QC Inspector is an employee of the Contractor and answers to a department head who is not connected with production. If this is not the case, an inherent conflict of interest may be present. The level of involvement of the QA agency is highly dependent upon the structure of the Contractor's QC program. If the Contractor's QC program is well organized, has competent inspection and testing personnel and is truly independent of production, the outside QA function can operate in the classical manner as an overseer where random spot inspection and testing will be sufficient. In the opposite case, where the QC department is less competent or is being managed by production, the QA agency must take a very active role and perform many of the QC duties.

The definitions of these roles can directly affect the project structure and associated budgets. The Owner cannot accurately budget for QA testing and inspection until the Contractor is selected and the QC program established. Alleviating this dilemma requires the Engineer to tightly specify the QC and QA programs.

5.6.2 Duties of the Special Inspector

The Special Inspector should ascertain that all materials comply with the Contract Documents, either by mill and product certifications and/or by testing. The Inspector should verify that all fabrication and erection, including welding and bolting, is performed in accordance with the Contract Documents.

The specific tasks of the Special Inspector should be defined in the Contract Documents. The Special Inspector may be assigned the task of evaluating the Contractor's QC program and its effectiveness. The Special Inspector should also verify the qualifications of the QC and QA Inspectors and the NDT technicians. The Special Inspector may be assigned all QA responsibilities, or may be assigned the task of supervising or monitoring QA performed by specific Welding Inspectors, NDT technicians or other Inspectors. Special Inspection may also include monitoring QC inspection performed by the Contractor.

All Inspectors, regardless of classification, shall keep written records of the inspections performed. Copies of these records should be distributed to those responsible for the inspection. Documents reporting nonconformance should be distributed to the Engineer, Owner, and/or Building Official as specified in the Contract Documents, and to the Contractor. Records documenting correction of nonconformance should be distributed to the same organizations as those receiving reports of nonconformance.

Upon completion of the Inspector’s tasks, the Inspector shall issue a written report stating that all work inspected under the Inspector’s charge meets the applicable codes and specifications, and that nonconformances have been corrected to the satisfaction of the Engineer.

The *UBC* includes the following tasks for the Special Inspector in section 1701.3:

> “The Special Inspector shall observe the work assigned for conformance to the approved design drawings and specifications. The Special Inspector shall furnish inspection reports to the Building Official, the Engineer or Architect of Record, or other designated persons.”

The *UBC* defines the types of work to be inspected by a Special Inspector in section 1701.5, listing structural welding and high-strength bolting specifically.

The *NBC* includes the following steel construction tasks for the Special Inspector in section 1705:

> “The Special Inspector shall keep records of all inspections. The Special Inspector shall furnish inspection reports to the code official, and to the registered design professional in responsible charge.
>
> The Special Inspector shall verify that the fabricator maintains detailed fabrication and quality control procedures which provide the basis for inspection control of the workmanship and the fabricator’s ability to conform to approved drawings, project specifications and referenced standards. The Special Inspector shall review the procedures for completeness and adequacy relative to the code requirements for the fabricator’s scope of work.
>
> The Special Inspector shall verify that the fabricator is properly implementing the fabrication and quality control procedures outlined.
>
> The Special Inspector shall perform an inspection of the steel frame to verify compliance with the details shown on the approved construction documents, such as bracing, stiffening, member locations and proper application of joint details at each connection.”

In the *NBC*, there are several other references to inspection being performed, but the individual or agency responsible for the inspection is not defined.

Under Section 1705.3, the draft *IBC* requires Special Inspection of welding to be in compliance with Section 6 of AWS D1.1. If further requires that Special Inspection include inspection of the steel frame to verify compliance with the details shown on the approved construction documents, such as bracing, stiffening, member locations and proper application of joint details at each connection. It also requires periodic inspection of the installation of high strength bolts, in accordance with nationally recognized standards.

5.6.3 Duties of the Structural Steel Inspector

The QA Inspector, whether Special Inspector or other type of Inspector, should verify that the Contractor follows the prescribed QC Program. This includes random spot checks verifying materials controls by grade identification, and specific verification of materials grade and any special requirements for those elements of the structure identified by the Engineer as needing QA verification.

5.6.4 Duties of the Welding Inspector

The Inspector should keep a record of all welders, welding operators and tack welders, all procedure and operator qualifications, all accepted parts, the status of all rejected joints, NDT test reports, and other such information as may be required.

The QA Welding Inspector should ensure that each welder, NDT technician and QC Inspector has a unique identification mark or die stamp to identify his or her welds/weld tests/weld inspections. The QA Inspector should ensure that the QC, QA and NDT personnel are keeping the proper records as listed in the previous paragraph.

The duties of the Welding Inspector, as designated under either QC or QA, may include the following items:

a) Review and understand the applicable portions of the Specifications, the Contract Drawings and the Shop Drawings for the project.

b) Verify that all applicable welding Procedure Qualification Records (PQRs), welder and welding operator qualifications and welding procedure specifications (WPSs) are available, current and accurate.

c) Verify that an approved Welding Procedure Specification (WPS) has been provided and that the WPS has been reviewed with each welder performing the weld. A copy of the appropriate WPSs should be at each joint. Welds not executed in conformance with the WPS should be considered rejectable.

d) Verify welder identification and qualification. Verify that any required supplemental qualification tests have been passed, and mock-ups, if required by the Contract Documents, have been executed.

e) Require requalification of any welder, welding operator or tack welder who has, for a period of six months, not used the process for which the person was qualified.

f) Check all mill certificates for material compliance with the project requirements.

g) Verify material identification per approved shop drawings and specifications.

h) Verify the electrode, flux and shielding gas specification sheets for compliance with the Contract Documents.

i) Identify welding consumables per approved shop drawings and approved WPS.

j) Make certain that all electrodes are used only in the permitted positions and within the welding parameters specified in the WPS.

k) At suitable intervals, observe joint preparation, assembly practice, preheat temperatures, interpass temperatures, welding techniques, welder performance and any postweld heat treatment to make certain that the applicable requirements of the WPS and Code are met.

l) Verify proper amperage and voltage of the welding process, if needed, by using a hand held calibrated amp and volt meter. Amperage and voltage should be measured at the arc with this equipment.

m) Inspect the work to ensure compliance with AWS D1.1. Size and contour of welds should be measured with suitable gauges. Visual inspection may be aided by a strong light, magnifiers, or other devices which may be helpful.

n) Schedule NDT technicians in a timely manner, after the visual inspection is complete and the assembly has cooled. For repair welding, the NDT should not be performed sooner than 48 hours after the welding is complete and cooled to ambient temperature.

o) Ensure that each welder has a unique identification mark or die stamp to identify his or her welds. The Inspector should also mark the welds / parts / joints that have been inspected and accepted with a distinguishing mark or die stamp, or alternatively, maintain records indicating the specific welds inspected by each person.

p) The accepted and rejected items should be documented in a written report. The report should be transmitted to the designated recipients in a timely manner.

5.6.5 Duties of the NDT Technician

The NDT technician should work closely with the Welding Inspector. The NDT technician(s) must perform all NDT required by the Contract Documents or by the Building Code. NDT should be performed in a timely manner, so as not to hinder production, but also to detect welding problems soon after occurrence so that corrective measures may be taken by the Contractor to rectify such problems.

The NDT technician should mark the welds / parts / joints that have been inspected and accepted with a distinguishing mark or die stamp, or alternatively, maintain records indicating the specific welds inspected.

The accepted and rejected items should be documented in a written report. The report should be transmitted to the designated recipients in a timely manner.

5.6.6 Duties of the Bolting Inspector

The Bolting Inspector should work closely with the Contractor and other Inspectors. The Bolting Inspector(s) must perform all inspections required by the Contract Documents, the Research Council on Structural Connections specifications, and the Building Code. Bolting inspection should be performed in a timely manner, so as not to hinder production, but also to detect bolting problems upon or soon after occurrence so that corrective measures may be taken by the Contractor to rectify such problems.

The Bolting Inspector should:

a) Review and understand the applicable portions of the specifications, contract drawings, shop detail drawings and erection plans for the project.

b) Verify that all applicable bolt installation procedures are available, current and accurate.

c) Verify that the appropriate bolt installation procedure has been provided and reviewed with each bolting crew member performing the work.

d) Check all manufacturer certifications for material compliance with the project requirements.

e) Verify bolting material identification.

f) Verify suitable, controlled storage conditions.

g) Observe required pre-installation testing performed at the start of the work for each assembly lot.

h) For the calibrated wrench method of installation, observe calibration of the wrench(s) at the start of each work shift.

i) Verify the suitability of the bolted joints, such as bolt hole size and condition, prior to assembly. Check for unfair reaming or slotting for poorly aligned holes.

j) For slip-critical joints, verify that the required faying surface conditions are met.

k) Prior to pretensioning, verify that all bolts have been installed and the joint brought to the snug tight condition.

l) Observe the pretensioning operation for proper application of the bolting procedures.

m) Arbitrate any disputes regarding achieved bolt pretension immediately upon installation of the bolts in dispute. Any appreciable delay in arbitration will result in considerable inaccuracies in the arbitration procedures provided by the RCSC specifications.

n) Complete a written report recording the joints observed, inspected, and accepted. The report should be transmitted to the designated recipients in a timely manner.