SHOP WELDING INSPECTION

GENERAL

This IM is compiled to set forth the general duties, responsibilities, and various phases of shop inspection of structural steel as follows:

1. Shop Welding Inspection
2. Materials Inspection
3. Shop Inspection
4. Design Inspection (Laydown Inspection)
5. Shop Documentation

The purpose of this IM is to establish a uniform application of the specifications, standardize fabrication inspection practices and procedures and to set guidelines and requirements for the inspector and the fabricator to ensure that all fabrication work performed will be in accordance with the contract documents

INSPECTOR DUTIES & RESPONSIBILITIES (Art. 1105.07 of the Standard Specifications)

The shop inspector functions as a judicial representative of the Iowa Department of Transportation and as such is the Quality Assurance Inspector (QA) as outlined in AWS Dl.5. The QA Inspector acts for and in behalf of the owner on all matters within the scope of the contract documents and the limits of authority delegated to him.

An inspector decision should be governed by written special provisions, standard specifications, and drawings, which he must be able to interpret.

INSPECTION REQUIREMENTS

In addition to the IMs, the state inspector will need the following:

A. Drawings
   1. Design drawings
   2. Approved Shop Drawings

B. Specifications & Other Documents
   1. Standard Specifications
   2. Supplemental Specifications
   3. Special Provisions
   4. AWS Bridge Welding Code, Dl.5 and/or D1.1

C. Other Inspection Publications
   1. AWS Publication Titled, Welding Inspection
   2. Highway Research Board Special Report No. 114 - Welded Highway Bridges, Analysis & Inspection Factors.

D. Inspection Tools & Safety Equipment
   1. Protective Glasses
   2. Tape and Rule
   3. Weld Gauge
   4. Paint Gauge
   5. Marking Crayons
   6. Micrometer or Vernier Caliper (for measuring thickness of plates)
   7. Surface Roughness Comparison Gauge
   8. Hard Hat
   9. Safety Shoes
   10. Halogen Flashlight

SHOP WELDING INSPECTION

A. WELD PROCEDURES

1. **Welding procedures** are an integral part of the shop drawings and must be approved before any welding is started.

   Welding procedures shall be distributed as part of the shop drawings.

   All welding procedures, except those for SMAW electrodes with a specified yield strength of less than 90 ksi (620 MPa) listed in Table 4.1, shall be subject to procedure testing or verification testing within the last 60 months before production welding, unless waived by the engineer.

   Welding procedures that require testing are controlled by the limitations found in the AWS Code, in Section 5, Qualification, with specific attention directed to 5.12, 5.13.

   The Central Materials Office shall approve changes in shop welding procedures prior to the start of the fabrication process.

2. **Welding sequence**. The sequence in welding and assembling of girders shall be to minimize distortion and shrinkage. Therefore, fabricators shall submit a welding sequence on large multiple web splices and multiple deck plate bridges in accordance with Article 3.4 of the AWS Code. All web splices must be completed and radiographs approved before fitting to flanges.

B. WELDER QUALIFICATION

Qualification tests are to determine a welder's ability to produce sound welds and should not be used as a guide for fabrication welding. The latter shall be performed in accordance with the requirements of the procedure specification.

Qualification of welders and semi-automatic welders may be for either limited [(3/4 in. (20.0 mm) maximum] or unlimited thickness for grooves and unlimited thickness for fillets.

Qualification of welding operators is for unlimited thickness only. Welding operators using multiple electrode equipment are required to be qualified using this equipment for the test which also qualifies them to use single electrode equipment. Twin arc process qualification does not qualify the operator for multiple electrode welding, such as tandem arc, etc.

For complete information on qualification tests see IM 559, Qualification Tests for Shop Welding.

Welders, welding operators and tackers may be required to be re-tested at any time there is a specific reason to question his/her ability to make sound welds.

C. WELDING MATERIALS

1. **Weldments** made on structural steel for bridges shall be made by any of the processes approved by the contract documents.

   These processes must use only approved electrodes, electrode and flux combination, gas and studs.

2. **Filler metal** must comply with the requirements of table 4.1 or 4.2 of the AWS D1.5 Specifications. Filler metal for bare applications of ASTM A709 GR 50 W steel shall comply with Table 4.3.

   The F6XX-flux combination is only permitted for welding of ASTM A709 GR 36 steel. The F7XX- flux combination may be used on all steels with a specified yield strength of 50,000 psi (345 MPa) or less.

3. **Weldability investigation**, if needed, shall be made in accordance with the current specifications.

4. **Storage and drying**. The storage or drying of all electrodes having low hydrogen covering shall be in accordance with paragraph 4.5.2 of the AWS D1.5 Specification. These electrodes shall be purchased in hermetically sealed containers or dried before using. Electrodes conforming to AWS A 5.1 and A 5.5 Specifications shall be re-dried no more than one time and any electrodes, which have been wet, shall not be used.

   The storage of submerged arc flux shall comply with article 4.8.3 of the AWS Code. Unused flux in open containers at the end of a day shall be returned to the drying oven or the top 1 in. (25 mm) of flux from the containers shall be discarded at the start of the next workday. Flux stored in an airtight container at the end of a day may also be used at the start of work the next day. Flux that has been wet shall not be used. Fused flux shall not be reused.

5. **Flux Reclamation –**. Saw Flux that has not been properly melted during welding may be reused after recovery by vacuuming, sweeping from weldment surfaces or by any other means shall be performed as required by AWS D1.5 – 4.8.4.

D. MATERIAL PREPARATION

1. **Joint Detail.** The inspection of the joint detail of weld procedures is to insure that the angle of the bevel, the depth of the root face and the width of the root opening are all in accordance with the established weld procedure. The tolerance of these dimensions is given in Paragraph 3.3.4 of the AWS Code. The surface roughness of the oxygen cut edges shall be as specified in Paragraph 3.2.2 of the AWS Code.

2. **Grinding.** Grinding may be used for the removal of all mill scale for web to flange welding. The removal of all mill scale includes the center of the flange area; the two sides of the web and the oxygen cut edge of the web. Grinding may also be used to make weld repairs, correct weld profiles, the removal of weld reinforcement, nicks, gouges, chain marks, beveling edges and etc. The tolerance for grinding butt welds is outlined in Paragraph 3.6.3 of the AWS Code.

3. **Tack welds.** Tack welds shall only be used as outlined in Paragraph 3.3.7 of the AWS Code.

   Tack welds are subject to the same quality requirements, including preheat, as the final welds except that: Preheat is not mandatory for single-pass tack welds, which are remelted, and incorporated into continuous submerged arc welds. Whenever an inspector questions the re-melting of a tack weld by a continuous submerged arc weld he may request a procedure test to ensure the tack weld has been remelted. No deviation from established procedures will be permitted for the test.

4. **Preheat.** Preheat and interpass temperatures are always a minimum specification requirement and should be considered as such. The inspector must remember there is no minus tolerance on preheat, but the plus tolerance is essentially unlimited on all steels except heat-treated steels. The minimum preheat and interpass temperature table including footnotes are found in the AWS Code, Table 4.4.

5. **Limitations.** Limitations are imposed on some type of welds, procedures and tacking. Limitations on the size of electrodes and the thickness of root passes and subsequent layers for manual shielded metal arc welding is outlined in Paragraph 4.6 of the AWS Code. Similar limitations for submerged arc welding are outlined in Articles 4.9, 4.10 and 4.11 of the AWS Code. Limitations on tack welds are outlined in Paragraph 3.3.7 of the AWS Code.

   Assembling procedures requiring tack welds, other than web to the flange, shall be submitted to the Design Bridge Engineer for approval. Tack welds outside the beveled area for flange run-off plates must have prior approval. These procedures shall be complete in detail as to weld size, location, preheat and their proper removal.

   No unauthorized temporary or permanent welds, if not shown on the plans or permitted by the specifications, shall be made without written authorization by the Bridge Engineer.

   Run off bars or extension plates shall be as outlined in Paragraph 3.12 of the AWS

Code. However, these bars or plates shall be removed and ground smooth before radiographic testing is started, as required by Paragraph 6.10.3.1 of the AWS Code. When plates have sufficient trim this requirement may be waived.

E. WELDING

1. **Welding** is permitted only where designated on the plans.

   Laminations that appear on the face of oxygen cut butt joints to be welded and are 1 in. (25 mm) or less in length need not be explored and no repair is required. If a fabricating shop wishes to explore and then seal this area to prevent its showing in a radiograph as a weld defect it may do so without the approval of the engineer, but with the inspector's knowledge. In the event the sealed off area shows up in the radiograph, it must be noted on the radiography report. Welding repairs on all other oxygen cut edges are not allowed without the approval of the engineer.

2. **Unsatisfactory welds** shall be corrected as outlined in Article 3.7 of the AWS Code.

   Tolerance for undercutting is .01 in. (0.25 mm) deep when its direction is transverse to the primary stress and 1/32 in. (0.8 mm) deep when its direction is parallel to the primary stress. Refer to Paragraph 6.26.1.5 of the AWS Code.

3. **Gouging** – where any carbon arc gouging or cutting is involved, proper gouging procedures shall be used to avoid the retention of carbon deposits and material or dross in the areas which to be welded. Air carbon arc gouged surfaces shall be ground to bright metal.

4. **Arc Strikes** – care shall be exercised to avoid “arc strikes” outside the area of permanent welds on any base metal. Cracks or blemishes caused by arc strikes shall require removal of all defects. Compliance with the requirements of section 3.10 of the AWS D1.5 Code shall be required.

5. **Tolerances** for weld profiles shall be as outlined in Article 3.6 of the AWS Code. The tolerance on fillet weld size shall be as outlined in Paragraph 9.21.1.7 of the AWS Code for minimum size. The maximum size fillet weld shall not be more than 1/8 in. (3 mm) over on either leg for fillet welds through 1/2 in. (12.7 mm).

6. A fillet weld shall be considered to overlap if a leg interferes in anyway with the true measurement of the fillet size when using a standard fillet gauge.

   Fillet weld profiles shall be corrected for excess covexity, overlap, oversize, long legs and unusual roughness.

   Welds with piping porosity (pin holes) shall be repaired only when outside the tolerance specified in Paragraph 6.26.1.6 of the AWS Code. When repairs are necessary it shall

be only after full removal of the defect. Grinding may be used as necessary for good workmanship and profile.

The maximum number of repairs to defective or unsound welds on butt weld splices shall be three unless otherwise approved by the engineer. (See revised Paragraph 3.7.8 of the AWS Code in the Standard Specifications, Article 2408.13).

Surface grinding of butt joints required to be flush shall be in accordance with Paragraph 3.6.3 of the AWS Code. Exempt from 3.6.3 are the web butt welds of exterior surfaces of exterior lines of beams or plate girders, and web and flanges of box girders. The actual thickness of the web and flanges cannot be reduced by more than 0.01 inch.

7. **Stud welding** shall comply with the requirements of AASHTO / AWS D1.5, 2002, Code Section 7. Except the stud welding shall be limited only to the automatic stud welding gun. No other welding process shall be accepted. Only studs listed on the approved shear stud list in IM 453.10 Appendix A, shall be used. Any other brands must submit their qualification test to the Iowa DOT Central Materials Labratory for testing and approval prior to incorporating into the project.

   A manufacturer certification of the studs used shall be required. The fabricator and / or the contractor shall provide certified copies of the stud manufacturer's test reports (up-dated copies) of the last completed set of in-plant quality control mechanical tests.

   Operator Qualification: The first two stud shear connectors welded on a member, after being allowed to cool, shall be bent to an angle of 30 degrees from their original axes by striking the studs with a hammer. If failure does not occur in the weld zone of either stud the operator shall be qualified. If failure occurs in the weld zone of either stud, the procedure shall be corrected and two more studs shall be welded to the member and tested. If either of the second two studs fails, additional welding shall be continued on separate plates until two consecutive studs are tested and found to be satisfactory. Two consecutive studs shall then be welded to the member, tested, and found to be satisfactory before the operator is found to be qualified. The QA inspector shall then document the test in his/her file with the name of the operator and date of test. Qualification of each operator must be documented at the start of each project.

   The workmanship of the studs shall be as outlined in Paragraph 7.4 of the AWS Code. No welding is to be done when the temperature is below 0°F (-18°C), or when the surface is wet or exposed to falling rain or snow.

   The first two studs welded on each member, after they have been allowed to cool, shall be bent to an angle 30 degrees from their original axes. If failure occurs in the weld zone of either stud the weld procedure shall be changed and two more studs welded and tested as above. This shall continue until two studs have been welded, tested and found satisfactory before welding is permitted to continue.

Members having less than 20 studs may be tested at the start of each day's production welding period in lieu of testing as in the preceding paragraph.

Visual inspection requirements of studs welded to a member shall consist of the following: A full 360-degree fillet weld, uniform height of all studs and a well-formed fillet with normal color. When visual inspection reveals any deviation from these items the studs shall be bent 15 degrees from its original axis. Studs showing less than 360 degree welds shall be bent in the opposite direction to the missing weld. Studs may have the weld to be repaired before bending by use of the shielded metal-arc process using low-hydrogen electrodes and a 5/16 in. (5mm) fillet weld. Note: The SMA process may be used only for stud weld repair.

Studs that crack either in the weld, the base metal or the shank shall be replaced. If 10 percent of the studs applied to any member requires bending the welding shall be stopped until the necessary changes are secured to produce satisfactory studs on the subsequent members. If conditions warrant the inspector may select a reasonable number of additional studs to be bent.

When studs fail they shall be removed and the replacement shall be made as follows: The area in the member where the replacement is made must be determined as to tension or compression and then the repair shall be made as outlined in Paragraph 7.7.5 of the AWS Code.

Studs shall be made from cold-drawn stock conforming to the requirements of ASTM A 108, specification for steel bars, carbon cold finished, standard quality grades, grades G10100 through G10200 inclusive, either semi-killed or killed deoxidation.

F. NONDESTRUCTIVE TESTING

When nondestructive testing is specified it shall be done in accordance with the specifications that are included in the AWS Code and the DOT Standard Specifications.

The QA inspector has the responsibility for the monitoring of the work being performed.

1. **Radiographic Inspection**: Personnel performing radiograph inspection shall be qualified in accordance with the American Society for Nondestructive Testing Recommended Practice No. SNT-TC-lA Supplement A. The qualification of the inspector shall be sent to the Iowa Department of Transportation, Structural Material Engineer, at Ames, Iowa. Notification on the disposition of the inspector qualification will be made to all parties concerned.

   The QA inspector shall have a copy of the acceptance of the radiographer's certification. Since the acceptance of this certification is on a three-year period, the inspector is responsible for checking on the yearly eye examination and that new certification is resubmitted at the end of the three-year period. He/she shall also ascertain that the radiographer uses satisfactory equipment and procedures.

The radiographic report shall contain the following information:

a. Agency name
b. Name, signature and level of the operator
c. Name, signature and level of supervisor, when required
d. Date of work
e. Radiograph location plan or sketch of member and inspected areas.
f. A list of all radiographs taken including retakes & repairs
g. A list to show tension and compression areas along with the letter "T" for tension and "C" for compression on the films, if tolerances for such are to be used.
h. The thickness of the pieces being butt-welded
i. Signature of the QA inspector for acceptance.

Punch marks or paint sticks to identify the weld location shall be located 1 1/2 in. (38 mm) from the centerline of the weld, 1 1/2 in. (38 mm) from each edge and one near the centerline of the flange when necessary to locate it. Lead markers shall locate the paint stick marks and burn lines when welding slabs.

The penetrameter size and thickness shall be as outlined in Table 6.1 of the AWS Code. The use of Wire Image Quality Indicators is prohibited. Penetrameters shall be placed on the source side as outlined in the AWS Code. The essential hole as outlined in Table 6.1 and identification number shall be visible on the films. Two or more penetrameters are required on any film 10 in. (250 mm) or longer including lapped films.

The density range for a radiographic film shall be between 2.5 – 3.5.

When shims are required to be placed under penetrameters, they shall be at least equal to the average thickness of the weld reinforcement of both the near and far side.

Films are to be free of processing marks and scratches per Paragraph 6.10.10.

The radiographic inspector will interpret and report all radiographs taken. The QA inspector will also inspect all radiographs and make a preliminary approval. The QA inspector will also fill out Form #193 and enclose it with the radiographer report and make sure all films are submitted to the DOT Office of Materials at Ames, Iowa for final disposition and reporting.

The fabricator shall identify on the shop drawings where splices are to be in tension, compression or reversal of stresses and the extent of the initial radiographic inspection.

When ultrasonic testing is required or if fracture critical materials are being tested the radiograph reports shall be accompanied by a copy of the ultrasonic testing reports.

2. **Magnetic particle inspection:** Personnel performing magnetic particle inspection shall be qualified in accordance with the American Society for Nondestructive Testing Recommended Practice No. SNT-TC-lA, Supplement B. The qualifications of this inspector shall be sent to the Iowa DOT Structural Materials Engineer, at Ames, Iowa. Notification on the disposition of the inspector qualification will be made to all parties concerned.

   The DOT inspector shall have a copy of the acceptance of the MPT inspector's certification. He/she shall also ascertain that satisfactory equipment and procedure is used.

   The documentation by the inspector shall include the following information:

   a. Agency name
   b. Name of inspector
   c. Name, signature and level of supervisor when required.
   d. Date of work
   e. Sketch of member and inspected area
   f. List any defective welds, their location and extent of repair
   g. Date of re-inspection when applicable
   h. A statement that inspection was conducted according to ASTM E709
   i. Signature of the QA Inspector acceptance

CHECKOFF LIST

1. Weld Procedures

2. Weld Sequence procedure when required

3. Welder Qualification
   a. Manual Shielded Metal Arc
   b. Semi-Automatic Welding

4. Welding Operator Qualification
   a. Automatic with single electrode
   b. Automatic with multiple electrodes

5. Tacker Qualification

6. Welding Materials
   a. Approved electrode list
   b. Approved wire flux combination list
   c. Drying and storage ovens
   d. Certification for gas when used

7. Joint Preparation
   a. Oxygen cutting
   b. Grinding and/or weld repair
   c. Joint detail

8. Preheat
    a. Tack welds
    b. Welding
    c. Welding repairs

9. Welding
    a. Only where designated on the plans.

No corrective welding of oxygen cutting or material defects without approval of the engineer.

10. Unsatisfactory Welds
    a. Undercutting
    b. Profile
    c. Pinholes

11. Stud Welding
    a. Approved certification
    b. Full collar - with proper profile and color
    c. Height
    d. Location as to tension, compression or reversal of stresses

12. Nondestructive Testing
    a. Radiographic Inspection
        1. Certification of operator
        2. Inspection of films
        3. Documentation
    b. Magnetic Particle Inspection
        1. Certification of operator
        2. Correct Amperage and spacing ratio
        3. Documentation

ADDITIONAL INFORMATION

RECOMMENDED COPPER WELDING CABLE SIZES

Power Source		AWG Cable Size for Combined Length of Electrode and Workpiece Cables				
Rating in Amperes	Duty Cycle %	0 to 50 ft. 0 to 15m	50 to 100 ft. 15 to 30m	100 to 150 ft. 30 to 46m	150 to 200 ft. 46 to 61m	200 to 250 ft. 61 to 76 m
100	20	6	4	3	2	1
180	30	4	4	3	2	1
200	60	2	2	2	1	1/0
300	60	1/0	1/0	1/0	2/0	3/0
400	60	2/0	2/0	2/0	3/0	4/0
500	60	2/0	2/0	3/0	3/0	4/0
600	60	2/0	2/0	3/0	4/0	*

*Use two 3/0 cables in parallel.

TYPICAL CURRENT RANGES FOR ELECTRODES IN AMPERES

Electrode Diameter in. (mm)	E-7016	E-7018	E-7028
3/32 in. (2.38 mm)	65-110	70-100	----------
1/8 in. (3.18 mm)	100-150	115-165	140-190
5/32 in. (3.97 mm)	140-200	150-220	180-250
3/16 in. (4.76 mm)	180-255	200-275	230-305
7/32 in. (5.56 mm)	240-320	260-340	275-365
1/4 in. (6.35 mm)	300-390	315-400	335-430
5/16 in. (7.94 mm)	375-475	375-470	----------

TEMPERATURE STICKS

Fahrenheit Temperature Sticks by Tempil are available as follows:

6° increments	100°-350°	50° increments	650°- 900°
12°-13° increments	350°-500°	Approx. 25° increments	900°-1050°
25° increments	500°-650°	50° increments	1050°-2500°