

# Dimensional Tolerances and Quality Control in Welded Steel Construction

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Recently the American Welding Society issued two regulations for welded construction—one for buildings and the other for bridges. A brief discussion is given of the pertinent clauses devised to provide an acceptable quality of workmanship and to specify the limits of dimensional deviation obtained in welded fabrication.

•FABRICATION tolerances in welded steel construction may be considered under two general headings: (a) tolerances pertaining to the dimensional makeup or configuration of a member built of welded parts, and (b) tolerances concerned with the quality or acceptability of the welds alone.

Certain configurational deviations are inherent in welded fabrication. Because of the generated intense heat of fusion and the subsequent cooling of the weld melt, some distortions in the assembly would occur, regardless of the care exercised. The extent of these distortions will vary, according to the geometry and retention of the assembly, the size and thicknesses of the components, and the type and sequence of welding. Allowable limits for such deviations are covered in two documents recently issued by the American Welding Society: Code for Welding in Building Construction, AWS D1.0-63; and Specifications for Welded Highway and Railway Bridges, AWS D2.0-63. The prescribed tolerances cover: (a) deviations from straightness for columns; (b) camber, sweep, warpage and web buckles for beam and girders; (c) deviations from flatness for seats and faying surfaces; and (d) variations in depths of built-up members.

These tolerances have created no serious problems, either in design or fabrication, to require reexamination or changes at this time. However, with the benefit of advanced welding technology and improved equipment and procedures, it may be possible in the future to fabricate welded assemblies conforming to still smaller dimensional tolerances than presently required or obtainable.

In contrast, the problem of acceptability tolerances for the weld itself is a thorny one. In reality, here we have two questions to answer. First, we must define an acceptable weld. Then, based on that definition, we must devise ways and means to assure that such a weld is obtained.

The AWS Building Code, under heading of Quality of Welds, defines an acceptable weld as follows:

(a) The weld shall be sound throughout. There shall be no crack in any weld or weld pass. The weld may be considered sound if it contains only slight porosity<sup>1</sup> or fusion defects<sup>2</sup> which are well dispersed.

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<sup>1</sup>Porosity signifies gas pockets and any similar generally globular type voids.

<sup>2</sup>Fusion defect signifies slag inclusions, incomplete fusion, inadequate penetration and similar generally elongated defects in weld fusion.

(b) Undercut shall not be more than 0.01 in. deep when its direction is transverse to the primary stress in the part that is undercut. Undercut shall not be more than  $1/32$  in. deep when its direction is parallel to the primary stress in the part that is undercut.

(c) Welds shall be free from overlap.

(d) All craters shall be filled to the full cross-section of the welds.

Under the same heading, the Bridge Specification gives the following:

(a) There shall be thorough fusion between weld metal and base metal and between successive passes in the weld. All craters shall be filled to the full cross-section of the weld.

(b) Welds shall have no cracks and, regardless of the method of inspection, shall have no other defects exceeding the following limits in size or frequency of occurrence:

(1) The greatest dimension of any porosity or fusion defect that is  $1/16$  in. or larger in greatest dimension shall not exceed the size Dimension of Defect, B, indicated in Fig. 409 [Fig. 1 herein] for the joint or weld throat thickness involved. The

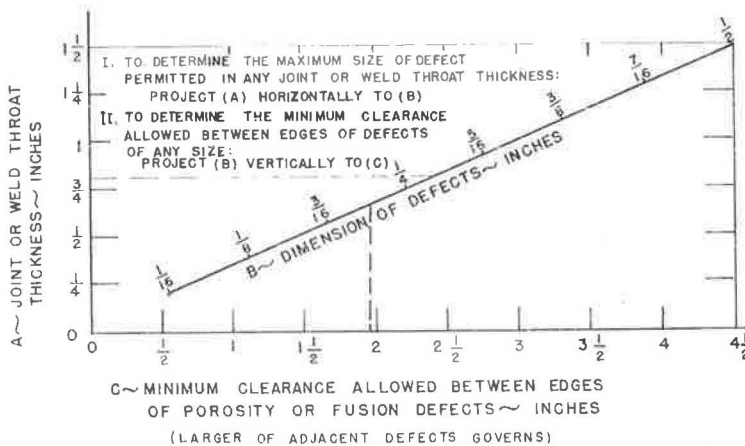


Figure 1. Weld quality requirements (limitations of porosity and fusion defects).

distance from any porosity or inclusion type defect to another such defect, to an edge or to the toe of a flange-to-web fillet weld shall not be less than the Minimum Clearance Allowed, C, indicated by Fig. 409 for the size of defect under examination. The limitations given by Fig. 409 for  $1\ 1/2$  in. joint or weld throat thickness shall apply to all joints or weld throats of greater thickness.

(2) The sum of the greatest dimensions of porosity and fusion defects less than  $1/16$  in. in greatest dimension shall not exceed  $3/8$  in. in any linear inch of weld.

(3) Undercut shall not be more than 0.01 in. deep when its direction is transverse to the primary stress in the part that is undercut. Undercut shall not be more than  $1/32$  in. deep when its direction is parallel to the primary stress in the part that is undercut.

(4) Convexity or reinforcement of a weld face shall not exceed the limits shown in Fig. 408C and 408E [Figs. 2C and 2E herein] and there shall be no overlap.

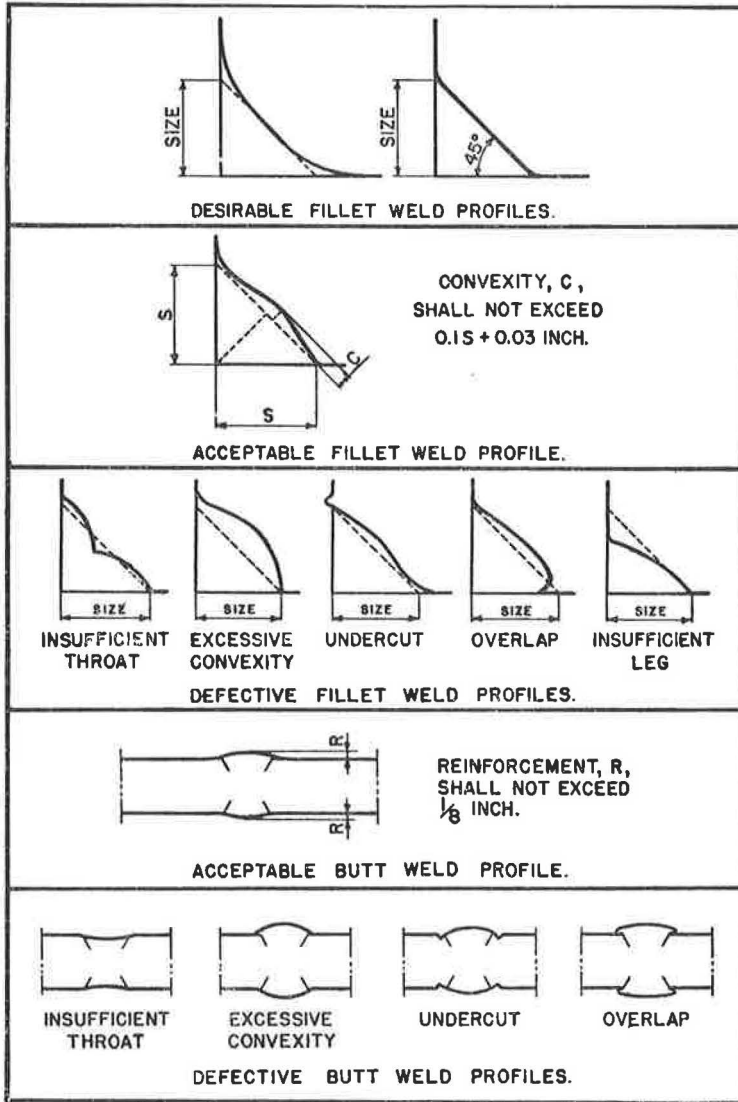


Figure 2. Weld profiles.

To restate these requirements more concisely: the weld must be free of visible and hidden defects as defined.

Visual inspection is a commonly utilized method of weld quality control. It constitutes the most practicable means for detecting visible defects. Defects pertaining to weld profiles or contours (Fig. 2) are easily observable. Fine surface cracks are revealed by means of devices such as strong lights and magnifiers.

As for the detection of hidden defects, code implementation is not clear. It is required that the welds be free of such defects, but tests needed for the purpose are not made mandatory. These are the so-called nondestructive tests, including the magnetic particle method, dye penetrants, ultrasonic testing, and radiography. It is stated, both in the Building and the Bridge Specifications, that such tests may be required to be conducted at the owner's expense. Testing cost could be considerable, but

more important is the eventual controversy connected to the evaluation of the test results. This is especially true when the device is radiography, which is the most thorough method for probing concealed weld defects. The revelation of the films is very much like opening Pandora's box. When applied to the framings of buildings, all such tests and consequent repairs invariably end up in litigation.

Present code requirements for weld quality are much too rigid for a reasonable assurance of adequacy. This is particularly true for the Building Code, which is concerned with structures designed for normal service loading where no fatiguing stress conditions prevail. In such applications some weld defects, such as possible inclusions, gas pockets, and even minor fusion faults, may be safely overlooked, without fear of impairment of structural adequacy. Radiography will reveal that defects of this nature are present in most all welded framings, yet the service performance of these structures, extending over periods of three decades or more, has amply demonstrated their dependability and strength. Therefore, at least in framings for buildings and other structures under similar loading, good visual inspection should generally suffice to assure an acceptable quality of welding. Only in instances where excessive cracking is observed should supplementary probing be undertaken. In such cases, use of magnetic particles or dye penetrants may be more dependable for disclosing the true extent of cracks prior to the needed repairs.

Use of ultrasonic testing and radiography should be confined solely to testing the soundness of welds in joints where cyclic stresses in the fatigue range would occur. Even in such applications, great care should be exercised in determining the extent of probing and in evaluating the importance of the revealed defects.

The economy of welded construction, and hence the scope of its utilization, is greatly dependent on code requirements. Extreme conservatism and needless restrictions in the form of unrealistic welding tolerances would limit the use of the technique and the profit to be obtained from its applications. The desired objective, the adoption of liberal welding tolerances consistent with safety, can only be achieved by close cooperation between code authorities and the various segments of the welding industry. Educational programs as well as pertinent research can play an important role in this task.