



Designation: A143/A143M – 07 (Reapproved 2020)

Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement¹

This standard is issued under the fixed designation A143/A143M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This practice covers procedures that can be followed to safeguard against the possible embrittlement of steel hot-dip galvanized after fabrication, and outlines test procedures for detecting embrittlement. Conditions of fabrication may induce a susceptibility to embrittlement in certain steels that can be accelerated by galvanizing. Embrittlement is not a common occurrence, however, and this discussion does not imply that galvanizing increases embrittlement where good fabricating and galvanizing procedures are employed. Where history has shown that for specific steels, processes and galvanizing procedures have been satisfactory, this history will serve as an indication that no embrittlement problem is to be expected for those steels, processes, and galvanizing procedures.

1.2 This practice is applicable in either inch-pounds or SI units. Inch-pounds and SI units are not necessarily exact equivalents. Within the text of this practice and where appropriate, SI units are shown in brackets.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recom-*

mendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 *ASTM Standards:*²

F606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets (Metric) F0606_F0606M

3. Terminology

3.1 *Definitions:*

3.1.1 *embrittlement, n*—the loss or partial loss of ductility in a steel where an embrittled product characteristically fails by fracture without appreciable deformation; types of embrittlement usually encountered in galvanized steel are related to aging phenomena, cold working, and absorption of hydrogen.

4. Factors in Embrittlement

4.1 Embrittlement or loss of ductility in steel is often associated with strain-aging. Strain-aging refers to the delayed increase in hardness and strength, and loss of ductility and impact resistance which occur in susceptible steels as a result of the strains induced by cold working. The aging changes proceed slowly at room temperature, but proceed at an accelerated rate as the aging temperature is raised and may occur rapidly at the galvanizing temperature of approximately 850 °F [455 °C].

4.2 Hydrogen embrittlement may also occur due to the possibility of atomic hydrogen being absorbed by the steel. The susceptibility to hydrogen embrittlement is influenced by the type of steel, its previous heat treatment, and degree of previous cold work. In the case of galvanized steel, the acid pickling reaction prior to galvanizing presents a potential source of hydrogen. However, the heat of the galvanizing bath partially expels hydrogen that may have been absorbed. In

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

practice hydrogen embrittlement of galvanized steel is usually of concern only if the steel exceeds approximately 150 ksi [1100 MPa] in ultimate tensile strength, or if it has been severely cold worked prior to pickling.

4.3 Loss of ductility of cold-worked steels is dependent on many factors including the type of steel (strength level, aging characteristics), thickness of steel, and degree of cold work, and is accentuated by areas of stress concentration such as caused by notches, holes, fillets of small radii, sharp bends, etc.

4.4 Low temperatures increase the risk of brittle failure of all plain carbon steels including steel that has been galvanized. The rate at which this temperature loss of ductility occurs varies for different steels. The expected service temperature should thus be taken into account when selecting the steel.

5. Steels

5.1 Open-hearth, basic-oxygen, and electric-furnace steels shall be used for galvanizing. Other materials that can be galvanized include continuous cast slabs, steel or iron castings, and wrought iron.

6. Cold Working and Thermal Treatment

6.1 For intermediate and heavy shapes, plates, and hardware, cold bend radii should not be less than that which is proven satisfactory by practice or by the recommendations of the steel manufacturer. These criteria generally depend on the direction of grain, strength, and type of steel. A cold bending radius of three times (3×) the section thickness, or as recommended in *AISC Manual of Steel Construction*,³ will ordinarily ensure satisfactory properties in the final product. Although sharper bending on thin sections can usually be tolerated, embrittlement may occur if cold bending is especially severe. If the design requires sharper bending than discussed herein, the bending should be done hot, or if done cold the material should be subsequently annealed or stress relieved as noted in 6.3.

6.2 Smaller shapes, including thickness up to ¼ in. [6.4 mm] may be cold worked by punching without subsequent annealing or stress-relieving. Shapes ⅝₁₆ to 1⅛₁₆ in. [8 to 18 mm] in thickness are not seriously affected as to serviceability by cold punching or if the punching is done under good shop practice. The heavier shapes, ¾ in. [19 mm] and over, shall be reamed with at least ⅛ in. [1.6 mm] of metal removed from the periphery of the hole after punching, or shall be drilled, or thermally treated prior to galvanizing as noted in 6.3.

6.3 Fabrication in accordance with the principles outlined in 6.1 and 6.2 will normally obviate the need for thermal treatment. However, if required, proper thermal treatment shall precede galvanizing of the steel. For heavy cold deformation exemplified by cold rolling, sheared edges, punched holes, or cold-formed rods and bolts, subcritical annealing at temperatures from 1200 to 1300 °F [650 to 705 °C] should be employed. For less severe cold deformation typified by cold bending, roll forming, etc., it is advisable to limit the thermal

treatment to stress relieving at a maximum of 1100 °F [595 °C] to avoid excessive grain growth or alternatively to fully normalize the steel at temperatures from 1600 to 1700 °F [870 to 925 °C]. The time at temperature should be approximately 1 h/in. [24 min/cm] of section thickness.

6.4 Flame cut copes on structural beams shall have a minimum radius of 1 in. [2.5 cm]. After cutting, the cut surface shall be ground to remove notches, grooves, and irregular surface features to leave the surface smooth.

7. Preparation for Galvanizing

7.1 Hydrogen can be absorbed during pickling and in some instances, as noted in 4.2, may contribute to embrittlement of the galvanized product. The likelihood of this, or of surface cracking occurring, is increased by excessive pickling temperature, prolonged pickling time, and poor inhibition of the pickling acid. Heating to 300 °F [150 °C] after pickling and before galvanizing in most cases results in expulsion of hydrogen absorbed during pickling.

7.2 Abrasive blast cleaning followed by flash pickling may also be employed when over-pickling is of concern or when very high strength steel, ultimate tensile strength higher than 150 ksi [1100 MPa], must be galvanized. The abrasive blast cleaning does not generate hydrogen while it is cleaning the surface of the steel. The flash pickling after abrasive blast cleaning is used to remove any final traces of blast media before hot-dip galvanizing.

8. Responsibility for Avoiding Embrittlement

8.1 Design of the product and selection of the proper steel to withstand normal galvanizing operations without embrittlement are the responsibility of the designer. The fabricator shall be responsible for employing suitable fabrication procedures. The galvanizer shall employ proper pickling and galvanizing procedures.

9. Testing for Embrittlement of Steel Shapes, Steel Castings, Threaded Articles, and Hardware Items

9.1 Subject to base material and dimensional limitations, the tests given in 9.2, 9.3, 9.4, or 9.5, or a combination thereof, shall apply. If one test specimen should be found embrittled by these tests, two additional specimens should be tested. Failure of either the second or the third specimen shall be cause for rejection of the lot (see Note 1) that the samples represent.

NOTE 1—A lot is a unit of production from which a sample may be taken for testing. Unless otherwise agreed upon by the manufacturer and the purchaser, or established within this practice, the lot shall be as follows: For test at a manufacturer's facility, a lot is one or more articles of the same type and size comprising a single order or a single delivery load, whichever is the smaller, or a smaller number of articles identified as a lot by the manufacturer, when these have been galvanized within a single production shift. For test by purchaser after delivery, the lot consists of the single order or the single delivery load, whichever is the smaller, unless the lot identity, established in accordance with the above, is maintained and clearly indicated in the shipment by the manufacturer.

9.2 A bend test for embrittlement of galvanized steel hardware such as bolts, pole and tower steps, braces, rods, reinforcing bars, etc., consists of bending the article and comparing the degree of bending to that which is obtained on

³ Available from American Institute of Steel Construction (AISC), One East Wacker Drive, Suite 3100, Chicago, IL 60601-2001. 9th Edition.