Guide for the Nondestructive Examination of Welds
Guide for the
Nondestructive Examination of Welds

4th Edition

Supersedes AWS B1.10:1999

Abstract

This guide acquaints the user with the nondestructive examination methods commonly used to examine weldments. The standard also addresses which method best detects various types of discontinuities. The methods included are visual, liquid penetrant, magnetic particle, radiographic, ultrasonic, electromagnetic (eddy current), and leak testing.
# Table of Contents

**Personnel** .................................................................................................................................................. v

**Foreword** ..................................................................................................................................................... vii

**List of Tables** .............................................................................................................................................. xi

**List of Figures** .............................................................................................................................................. xi

1. **General** ......................................................................................................................................................... 1
   1.1 Scope ......................................................................................................................................................... 1
   1.2 Advantages and Limitations of the Examination Method ................................................................. 1
   1.3 Acceptance Standards .............................................................................................................................. 1
   1.4 Cost ............................................................................................................................................................ 1
   1.5 Procedures .............................................................................................................................................. 2
   1.6 NDE Symbols ......................................................................................................................................... 2
   1.7 Safety and Health ................................................................................................................................. 2
   1.8 Standard Units of Measurement ........................................................................................................... 2

2. **Normative References** .............................................................................................................................. 2

3. **Terms and Definitions** .................................................................................................................................. 2

4. **Discontinuities** ........................................................................................................................................... 2
   4.1 Discussion of Discontinuities ................................................................................................................... 2
   4.2 List of Discontinuities ............................................................................................................................ 3
   4.3 Porosity ................................................................................................................................................... 4
   4.4 Inclusions ............................................................................................................................................ 6
   4.5 Incomplete Fusion ............................................................................................................................... 8
   4.6 Incomplete Joint Penetration .............................................................................................................. 8
   4.7 Undercut ............................................................................................................................................. 8
   4.8 Underfill ............................................................................................................................................. 9
   4.9 Overlap .............................................................................................................................................. 9
   4.10 Lamination ....................................................................................................................................... 9
   4.11 Delamination .................................................................................................................................. 10
   4.12 Seams or Laps .................................................................................................................................. 10
   4.13 Lamellar Tear .................................................................................................................................. 11
   4.14 Cracks ............................................................................................................................................. 11
   4.15 Concavity ....................................................................................................................................... 14
   4.16 Convexity ....................................................................................................................................... 14
   4.17 Weld Reinforcement ......................................................................................................................... 14

5. **Nondestructive Examination Methods** .................................................................................................... 15
   5.1 Visual (VT) ....................................................................................................................................... 15
   5.2 Liquid Penetrant (PT) ........................................................................................................................ 16
   5.3 Magnetic Particle (MT) ...................................................................................................................... 18
   5.4 Radiographic (RT) ............................................................................................................................. 20
   5.5 Ultrasonic (UT) ................................................................................................................................ 24
   5.6 Electromagnetic (ET) .......................................................................................................................... 29
   5.7 Leak (LT) ........................................................................................................................................... 31

6. **Interrelationships Among Welding Processes, Discontinuities, and Examination Methods** ............... 32
List of Tables

Table | Page No.
--- | ---
1 | Common Types of Discontinuities
2 | Discontinuities Commonly Encountered with Welding Processes
3 | Common Weld Examination Methods vs. Discontinuities
4 | Applicable Examination Methods—Five Weld Joint Types

List of Figures

Figure | Page No.
--- | ---
1 | Double-V-Groove Weld in Butt Joint
2 | Single-Bevel-Groove and Fillet Welds in Corner Joint
3 | Double-Bevel-Groove Weld in T-Joint
4 | Double Fillet Weld in Lap Joint
5 | Single Pass Double Fillet Weld in T-Joint
6 | Single-Bevel-Groove Weld in Butt Joint
7 | Fillet Weld Terminology
8 | Fillet Weld Discontinuities
9 | Groove Weld Terminology
10 | Groove Weld Discontinuities
11 | Steps in Penetrant Testing
12 | Magnetic Field Leakage
13 | Direct Magnetization Using dc Prods
14 | Indirect Magnetization Using a Yoke
15 | Making a Radiograph
16 | Radiographs of Weld Discontinuities and Macrosections
17 | Detection of Planar Discontinuities at Various Orientations by Radiography
18 | Block Diagram, Pulse-Echo Flaw Detector
19 | Similarities Between Reflections of Light and Sound at Boundaries
20 | Refraction
21 | Diffraction
22 | Example of Longitudinal Testing
23 | No Discontinuities
24 | Discontinuity
25 | Backing Bar False Indication
26 | Eddy Current Weld Examination
27 | Encircling Coil for the Eddy Current Examination of Welded Pipe
28 | Typical Eddy Current Surface Probes for the Examination of Welds
B.1 | Supplementary Nondestructive Examination Symbols
B.2 | Standard Location of the Elements in the Nondestructive Examination Symbol
1. General

1.1 Scope. This standard provides a reference guide for the kinds of nondestructive examination methods that are used to verify that welds meet the requirements of a code or specification. The nondestructive examination methods described are:

1. Visual (VT)
2. Liquid Penetrant (PT)
3. Magnetic Particle (MT)
4. Radiographic (RT)
5. Ultrasonic (UT)
6. Electromagnetic (Eddy Current) (ET)
7. Leak (LT)

The types of discontinuities detected with each method are disclosed and their causes discussed. Acceptance criteria are not addressed in this standard. Requirements for nondestructive examination and acceptance criteria should be specified in procurement documents prior to the award of contracts.

Nondestructive examination (NDE) is a general term used in this text to identify the common examination methods used for evaluation of welds and related materials without destroying their usefulness.

Principal factors to consider when choosing an examination method are the advantages and limitations of the method, anticipated type and size of discontinuity, acceptance standards, and cost. Annex A is a guide to process selection.

AWS has chosen nondestructive examination (NDE) as the preferred terminology for these inspection methods. In other standards, literature, and industry usage, other expressions are commonly used. Among these are: nondestructive evaluation (NDE), nondestructive inspection (NDI), and nondestructive testing (NDT). It must be emphasized that all of these expressions are commonly used and may be considered equivalent.

1.2 Advantages and Limitations of the Examination Method. The advantages and limitations of the examination method help to determine which method(s) is (are) best for detecting discontinuities of a particular size, shape, and orientation. For example, radiography can detect discontinuities with major planes aligned parallel with the radiation beam, such as cracks oriented normal to material surfaces. Radiography, however, usually cannot detect laminations in material or cracks oriented parallel to the plate surface. Conversely, ultrasonic examination can detect cracks oriented in any direction provided the sound beam is oriented essentially perpendicular to the major axis of the crack.

1.3 Acceptance Standards. The statement “the weld shall be radiographically examined” is incomplete unless acceptance standards are specified. Acceptance standards define characteristics of discontinuities and state whether particular types of discontinuities are allowed. Certain discontinuities such as slag or porosity may be acceptable providing their size and distribution are within specified limits. These criteria have to be incorporated in the acceptance standards. Most codes and specifications such as AWS D1.1, Structural Welding Code—Steel, ASME Boiler and Pressure Code, and API 1104, Welding of Pipeline and Related Facilities, contain acceptance standards. These and other construction standards are shown in Annex C.

1.4 Cost. Costs of the various examination methods depend on the particular situation. Two factors that should be considered in selection of a nondestructive examination method are the cost of performing the examination and the equipment.