

AEROSPACE RECOMMENDED PRACTICE

SAE ARP1317

REV.
A

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Superseding ARP1317

Electron Beam Welding

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1. SCOPE:

1.1 Purpose:

This Aerospace Recommended Practice (ARP) describes techniques recommended for use in producing electron beam welded joints in materials commonly employed in the aerospace industry.

1.2 Application:

The guidelines herein are oriented toward the use of welding equipment capable of maintaining the workpiece at pressure levels of 1×10^{-4} Torr (133×10^{-4} Pa) or lower during welding.

1.3 Radiation Hazard:

When operating, electron beam welding machines create radiation.

Guidelines and procedures referenced herein regarding radiation levels are contained in U.S. Department of Commerce, Bureau of Standards Handbook No. 60, "X-ray Protection".

- 1.3.1 Safety - Hazardous Materials: While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

1.4 Discussion of Process:

- 1.4.1 Description of the Process: Electron beam welding is a process wherein coalescence of adjacent metal surfaces is produced by the heat obtained from a concentrated beam composed primarily of high-velocity electrons impinging on the surfaces to be joined. In the type of equipment used primarily in aerospace applications, welding is performed in a vacuum chamber in which both the work piece and the electron gun are at pressure levels of 1×10^{-4} Torr (133×10^{-4} Pa) or lower. Welding voltage levels used are normally in the range of 30 to 150 kV at currents up to 1 A.

1.4.2 Advantages of the Process:

- 1.4.2.1 Depending on the power of the machine, butt joints over 5.0 in (127 mm) thick can be produced in most weldable materials in a single pass because of the very high energy density available with the process.
- 1.4.2.2 Welds can be produced with a very high depth-to-width ratio with correspondingly narrow heat-affected zones. Shrinkage and distortion are minimized, and, with some alloys, metallurgical and mechanical property changes between the parent metal and the weld zone are small when compared with most other fusion welding processes.

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- 1.4.2.3 It is often possible to weld joints that would be inaccessible to other fusion welding processes because welds can be made with the joint more than 24 in (610 mm) from the electron gun (depending on gun design and accelerating voltage).
- 1.4.2.4 Different alloys within any one material group may be welded together; in some cases, alloys from different groups may also be welded (see 3.2).
- 1.4.2.5 Metals reactive with the atmosphere can be welded without atmospheric contamination because welding is performed in a vacuum.
- 1.4.3 Limitations of the Process:
 - 1.4.3.1 The size of assemblies that can be welded is often limited by the vacuum-chamber size. However, in some instances, special chambers can be used that attach to the assembly at the weld joint and avoid the necessity of placing the entire assembly in the chamber.
 - 1.4.3.2 Close tolerances are required in detail parts to achieve the degree of accuracy required in fit-up to make an acceptable weld.
 - 1.4.3.3 The addition of filler metal is more difficult than with other fusion welding processes.
- 1.4.4 Definitions of the terms used herein and specific application of nondestructive testing techniques are contained in ARP1333 and AWS A3.0.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

2.1.1 Aerospace Material Specifications:

AMS-2630	Ultrasonic Inspection, Product Over 0.5 inch (12.7 mm) Thick
AMS-2631	Ultrasonic Inspection, Titanium and Titanium Alloy Bar and Billet
AMS-4185	Filler Metal, Aluminum Brazing, 12Si (4047)
AMS-4190	Aluminum Alloy Welding Wire, 5.2Si (4043)

2.1.2 Aerospace Recommended Practices:

ARP1333	Nondestructive Testing of Electron Beam Welded Joints in Titanium-Base Alloys
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2.2 U.S. Government Publications:

Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

NBS Handbook No. 60 X-ray Protection
MIL-STD-1595 Qualification of Aircraft, Missile and Aerospace Fusion Welders

2.3 AWS Publications:

Available from American Welding Society, P.O. Box 351040, Miami, FL 33135-1040.

AWS A3.0 Welding Terms and Definitions
AWS F2.1 Recommended Safe Practice for Electron Beam Welding and Cutting

3. TECHNICAL REQUIREMENTS:

3.1 Design Considerations:

- 3.1.1 Joints should be located to provide adequate accessibility for the particular type of electron beam gun to be used.
- 3.1.2 Joints should be accessible for adequate inspection and nondestructive testing.
- 3.1.3 Joints should be located so that the beam does not pass so near other structures as to cause beam deflection. The specific distance at which the beam can be affected will depend on the type of gun being used, the welding parameters, and the magnetic characteristics of the material or electromagnetic equipment, and the possibility of electrostatic charge buildup which could cause beam deflection.
- 3.1.4 Highly-stressed joints, where possible, should be reinforced (thickened) to reduce stresses in the weld below those in the surrounding structure.
- 3.1.5 For linear welds, elimination of those portions of the weldment where the beam starts and stops may be desirable. Starting and stopping the weld in areas that will be removed by subsequent machining or the use of run-off tabs have both been successfully used.
- 3.1.6 When possible, joints should be designed so that the root of the weld can be removed by machining.

3.2 Materials:

Electron beam welding can be used to join each individual alloy to itself. Electron beam welding can normally be used to join different alloys in the same alloy system. Alloys in one system should not be welded to alloys in another system without extensive investigation prior to the establishment of such bi-metal combinations. Those alloys in the "recommended" (REC) groups can normally be welded using standard procedures. Those alloys designated "difficult" (Diff) require special precautions or procedures; for example, CRES 347 and free machining steels often exhibit hot-short cracking. Alloys that are not generally weldable by other fusion methods should be explored before committing to electron beam welding.

Alloy System	Groups	Special Requirements
Aluminum and Aluminum Alloys	Rec: All fusion-weldable alloys	1. 2219 should have no filler.
	Diff: Most 2XXX and 7XXX alloys	2. 6XXX series alloys may require a high silicon content filler such as AMS-4185 or AMS-4190.
Magnesium Alloys	Rec: All fusion-weldable alloys	1. Backup strips may be required to minimize under-cutting 2. Because extensive vaporization will occur, special techniques may be required to protect the electron gun.
Copper Alloys	Rec: All fusion-weldable alloys	1. With more than approximately 2% lead or more than 7% zinc, or both, extensive vaporization will occur. Special techniques may be required to protect the electron gun.
	Diff: Alloys containing more than 8% lead	

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Alloy System	Groups	Special Requirements
Iron alloys with a nominal chromium content of 11% or less	Rec: All fusion-weldable alloys with a carbon content of 0.45% or less Diff: A Alloys with a carbon content over 0.45% B Free machining alloys C Rimmed or capped steels	1. Preheat is normally required if carbon content exceeds 0.30%, thickness exceeds 0.5 in (12.7 mm), or both. 2. Preheat and postheat may be required for higher alloy grades. 3. The addition of aluminum foil may be required for semi-killed, rimmed, or capped grades. 4. Special fillers may be required for some alloys.
Corrosion-Resistant Steels	Rec: A All fusion-weldable 200, 300, and 400 series alloys except 347 B All fusion-weldable precipitation hardening grades Diff: A Free machining alloys B 347	1. Preheat is normally required if carbon content exceeds 0.20%, thickness exceeds 0.5 in (12.7 mm), or both. 2. Preheat and postheat may be required for other alloys. 3. Precipitation hardening grades often weld well when aged at 1050 °F (566 °C) or higher.
Nickel and its alloys	Rec: All fusion-weldable alloys	
Cobalt and its alloys	Rec: All fusion-weldable alloys	
Titanium and its alloys	Rec: All fusion-weldable alloys	
Refractory Metals	Rec: All fusion-weldable alloys	
Ta-Cb Group		
Tantalum and its alloys		
Columbium and its alloys		
Tungsten-Molybdenum Group		Mechanical properties may limit applications.
Tungsten and its alloys		
Molybdenum and its alloys		Preheat is normally required.