***A Guide to the
Acceptance Criteria for
Radioisotopic Heat Sources***

D. L. Coffey

February 20, 1974

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MOUND LABORATORY

Miamisburg, Ohio

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ABSTRACT

During the development phases of heat source programs (the fabrication for design verification, engineering evaluation, etc.), heat sources and test capsules are often required prior to the formalization of specifications and drawings. Furthermore, there are also programs where the quantities and technology are such that a detailed and unique set of documentation is not justified. Consequently, this document is intended to be a general guide to the criteria applicable in evaluating the acceptability of radioisotopic heat sources and test capsules when they are produced under these circumstances. The guidelines are general in nature, since many applications of heat sources have unique requirements, but typical values are given where practicable. This document is written in the format of a general specification to enhance its usefulness.

INTRODUCTION

Scope This document is a general guide to the criteria to be used in evaluating the acceptability of radioisotopic heat sources or test capsules at the time of their production. It is applicable to those heat sources which do not have a formal product index nor specifications and drawings at the time of production; i.e., sources to be used as calorimetry standards, "engineering evaluation" heat sources, design verification units, etc. The guidelines are general in nature, since many applications of heat sources have unique requirements, but typical requirements are given where appropriate. In the absence of any other documentation, any deviations from the normal requirements should be recorded.

DOCUMENTATION

Applicable Documents All of the following documents should be available at the time of production if they exist: sketches and/or drawings of subassemblies and final assemblies, specifications or other documents which cover all the materials of construction including the radioisotopic fuel, any vendor certifications and/or chemical and physical data relating to these materials, any additional documents which define the user requirements, such as thermal output, etc., and a build sheet which defines the hardware to be used and which specifies the known portions of the manufacturing progress.

Reference Documents Any documents relating to Quality Control policies, disposition of materials, serialization of heat sources or components, fabrication procedures, weld schedules, etc., should be conformed to whenever practicable.

FABRICATION

Assembly and Welding Atmospheres Atmospheric conditions during the assembly and welding of heat source components should be documented. Impurity levels in inert gases and/or the results of appropriate bend tests, pressures during electron-beam (EB) welding, torch gases, etc., should be recorded.

EB welding of typical heat source materials should normally be performed at pressures less than 5×10^{-4} torr.

Refractory alloys and other materials which are susceptible to embrittlement by atmospheric impurities should be welded in inert gases such as argon or helium which have typical impurity levels that are less than: 35 ppm O₂, 160 ppm N₂, and 60 ppm H₂O.

However, overall system requirements may define different purity levels.

Weld Repair The repair of weld defects should be acceptable in most instances, although there may be specific cases where it is not. If weld repair is acceptable, repairs usually can be made by either rerunning the weld with the same automatic welding schedule, by an autogenous manual repair, or by a manual repair which utilizes filler material that complies with the chemical composition of the base metal specification. Repaired welds should pass the same requirements as non-repaired welds.

Example Welds One example weld should normally be made prior to each production run as a minimum requirement. Subassembly welds which can be given detailed inspections without the constraints imposed by radioactivity and thermal output may not require example welds. For the purpose of meeting the example weld requirement, the welding performed by the same operators with the same equipment on one joint design in one continuous work period is typically defined as a production run.

WELD INTEGRITY AND QUALITY CONTROL

Weld Acceptance Criteria

Visual Inspection All example and production welds should be given a visual inspection at the highest practical magnification, up to about 50X (1X may be the highest practical magnification for radioactively contaminated inner components), to determine if each weld meets the following representative criteria.

Cracks Usually there should be no visible cracks in the weld or in the adjacent base metal.

Surface Pores Under most conditions there should be no surface pores in the weld which exceed 0.010 in. diam. The total area of the surface porosity in one linear inch of weld typically should not exceed two percent of an area equal to (1 x T) square inches, where T equals the thickness of the thinnest member.

Dye Penetrant Inspection Generally, all example and production welds which are not radioactively contaminated and have surface temperatures less than about 150°F (under the inspection conditions) should be given a dye penetrant inspection. Rough or coated components are normally excluded from this inspection which uses an ultra sensitive fluorescent dye penetrant to determine if each weld meets the following typical criteria.

Cracks Commonly there should be no well defined cracks in the weld or in the base metal adjacent to the weld.

Surface Pores Typically, there should be no surface pores in the weld which exceed 0.010 in. diam. The total area of the surface porosity in one linear inch of weld normally should not exceed two percent of an area equal to $(1 \times T)$ square inches, where T equals the thickness of the thinnest member.

Metallographic Inspection In most cases, a minimum of one representative transverse section should be removed from the example weld for evaluation. And, if practicable, it is generally preferable to perform a quick metallographic analysis of the specimen prior to production welding. Also, the specimen should be properly prepared, visually examined, and photographed at a magnification of 20 to 75X to determine if the welds meet the following type of criteria.

Cracks There should be no cracks in the weld or the base metal adjacent to the weld unless permitted by design considerations.

Pores All pores should be generally circular in shape with no sharp corners or tails. Heat source welds should not contain single pores that are larger than 35% of the thickness of the thinnest member. However, special requirements or unique materials may alter this size criteria. And there may be any number of pores in one transverse section provided the total cross-sectional area of all the pores does not exceed that of a single pore of the maximum allowable size.

Weld Penetration and/or Fusion Generally heat source welds should not display any lack of penetration or fusion. A weld is normally defined as having 100% penetration when the weld bead completely obliterates the joint and has a thickness equal to the thickness of the thinnest member being welded. The weld may be acceptable if the joint is fused for part of its cross section and diffusion bonded for the remainder. Special conditions may require a partial penetration weld (e.g. 50%) or a seal weld (gas tight only).

Radiography Typically all production welds in the major containment member (strength member) and any other critical welds should be radiographed. Members of the capsule which may be radioactively contaminated or require a seal-type weld only are usually excluded from this inspection.

Radiographic Inspection Criteria In most cases, the crack and penetration requirements are the same as those listed for the metallographic inspection (q.v.). All radiographically detectable pores should be generally circular in shape with no sharp corners or tails. There should be no single pore with a diameter greater than 35% of the thickness of the thinnest member in most applications. Generally, the total projected area of the porosity in one linear inch of weld should not exceed two percent of an area equal to $(1 \times T)$ square inches, where T equals the thickness of the thinnest member.

Leak Test Each capsule subassembly which is sealed may be subjected to a helium leak check utilizing a mass spectrometer type detector. Typical maximum permissible leak rates are in the 10^{-5} to 10^{-6} std cc/sec range. Rough surfaces or coatings may require higher permissible leak rates due to surface retention if the subassembly is exposed to a helium atmosphere.

Other Tests Any additional operations, tests, or inspections which are considered necessary to ensure the quality of the completed heat source(s) may be performed. Any nondestructive test (NDT) methods (such as ultrasonics, eddy currents, etc.) can be used if adequate techniques have been developed for a given heat source design.

Quality Control A QC program should be applied to production operations when practicable to provide additional assurance that the materials used are adequately characterized and traceable to the final product and that applicable manufacturing procedures and tests are performed.

Data Package All data acquired while meeting all or any part of the above criteria should be documented and retained for an appropriate period of time.

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