Current Practice and Future Possibilities for Surveillance Program Design and Embrittlement Trending

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Introduction

This paper addresses two topics. First the requirements of surveillance programs that track the irradiation embrittlement of nuclear reactor pressure vessel (RPV) steels, and how these requirements have evolved over time, is addressed. Second the embrittlement trend curves (ETCs) that are developed as mathematical representations of data collected from these programs (and other sources) are discussed, including a discussion of recent activities within the American Society for Testing and Materials (ASTM) dedicated to this topic.

Surveillance Program Design

The earliest guidelines concerning a surveillance program to track the irradiation embrittlement of nuclear RPV steels were published in 1961 as ASTM Standard Practice E185. This practice, which has evolved through multiple revisions to its current version (E185-10), includes recommendations in four areas: what types of specimens should be tested, what materials from the RPV should be monitored, how the radiation and environmental conditions to which these materials are subjected should be established (especially with respect to how the conditions of the surveillance specimens relate to the conditions in the RPV wall), and also recommendations on how sampling is to be performed (including, for example, the capsule pull schedule, the location in the weld, plate, or forging from which mechanical test samples should be removed, etc.). Early recommendations relied on judgement due to the then nascent state of commercial generation of electricity by nuclear means. In this presentation an early evaluation of surveillance practice and requirements in the United States is reviewed to provide a perspective on the basis of some requirements that remain to this day. Additionally, the evolution of these requirements is tracked (see Figure 1). Commentary is also provided on current international practices, and on some possibilities for further refinement of surveillance requirements in the future.

Embrittlement Trend Curves (ETCs)

Beginning in the 1970s ETCs were developed from the surveillance data generated by E185 (and the like) monitoring programs. ETCs provide mathematical models that express the joint effects of exposure conditions and steel composition on the change in mechanical properties (predominantly Charpy transition temperature shift (ΔT_{41J}), but also Charpy upper shelf energy drop (ΔUSE) and, more recently, fracture toughness transition temperature shift (ΔT_o)) caused by neutron irradiation. Figure 2 illustrates the considerable activity during the last decade in the development and, in some cases, codification of new ΔT_{41J} ETCs. This presentation includes a discussion of on-going activities within ASTM Subcommittee E10.02 on the *Behaviour and Use of Nuclear Structural Materials* to statistically evaluate these ETCs with respect to available

[1] The opinions expressed here are those of the author alone. They do not represent an official position of the United States Nuclear Regulatory Commission.

surveillance data from commercial power reactors. The aim of this evaluation is to provide a recommendation on a potential revision to the ETC appearing in ASTM Standard Guide E900, "Predicting Radiation-Induced Transition Temperature Shift in Reactor Vessel Materials."

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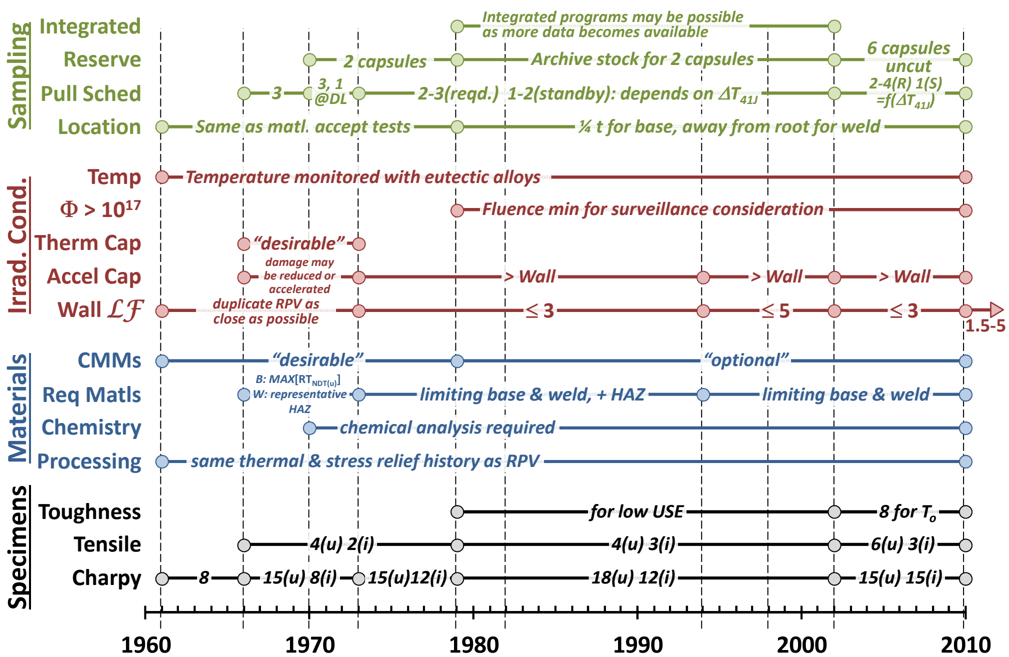

Figure 1: Evolution of the various requirements of ASTM Standard Practice E185, *Design of Surveillance Programs for Light-Water Moderated Nuclear Power Reactor Vessels*, from its first publication in 1961 until the current day. Vertical dashed lines indicate dates of E185 revision.

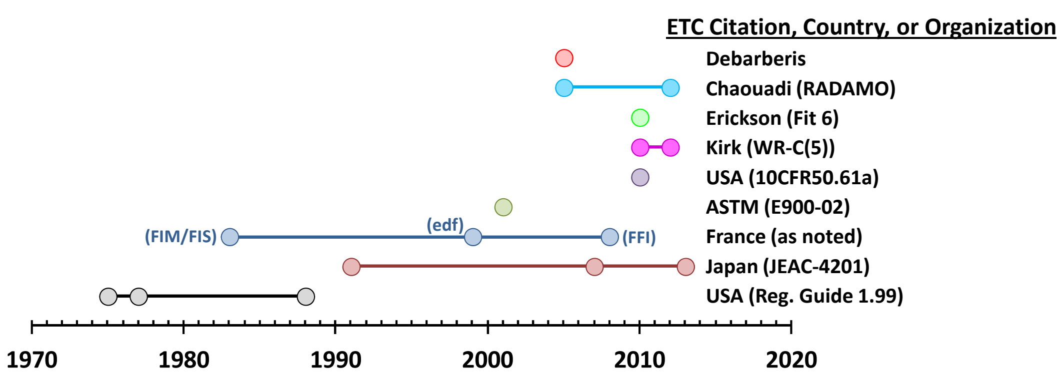

Figure 2: Timeline giving the adoption and/or publication dates of various ΔT_{41J} ETCs that have been adopted by various countries, by codes and standards organizations, or appearing in the technical literature. (*n.b.*, This list is an incomplete representation of the totality of ETCs; it is provided to illustrate the increased ETC development activity in the last decade).