Neutron irradiation of 9-12% Cr ferritic/martensitic steels below 425-450°C produces microstructural defects that cause an increase in yield stress and ultimate tensile strength. This irradiation hardening causes embrittlement, which is observed in Charpy impact and toughness tests as an increase in ductile-brittle transition temperature (DBTT). Based on observations that show little change in strength in these steels irradiated above 425-450°C, the general conclusion has been that no embrittlement occurs above this irradiation-hardening temperature regime.

In a recent study of F82H steel irradiated at 300, 380, and 500°C, irradiation hardening—an increase in yield stress—was observed in tensile specimens irradiated at the two lower temperatures, but no change was observed for the specimens irradiated at 500°C. As expected, an increase in DBTT occurred for the Charpy specimens irradiated at 300 and 380°C. However, there was an unexpected increase in the DBTT of the specimens irradiated at 500°C.

The observed embrittlement was attributed to the irradiation-accelerated precipitation of Laves phase. This conclusion was based on results from a detailed thermal aging study of F82H, in which tensile and Charpy specimens were aged at 500, 550, 600, and 650°C to 30,000 h. These studies indicated that there was a decrease in yield stress at the two highest temperatures and essentially no change at the two lowest temperatures. Despite the strength decrease or no change, the DBTT increased for Charpy specimens irradiated at all four temperatures. Precipitates were extracted from thermally aged specimens, and the amount of precipitate was correlated with the increase in transition temperature. Laves phase was identified in the extracted precipitates by x-ray diffraction.

Earlier studies on conventional elevated-temperature steels also showed embrittlement effects above the irradiation-hardening temperature regime. Indications were that this embrittlement was also caused by irradiation-accelerated or irradiation-induced precipitation. These observations of embrittlement in the absence of irradiation hardening have been examined and analyzed with computational thermodynamics modeling to illuminate and understand the effect.