3.6 Primary System Boundary

Applicability:

Applies to the operating status of the reactor coolant system.

Objective:

To assure the integrity and safe operation of the reactor coolant system.

Specification:

A. Thermal and Pressurization Limitations

1. The average rate of reactor coolant temperature change during normal heatup or cooldown shall not exceed 100°F/hr when averaged over a one-hour period.

2. or ~~D~~during operation where the core is critical, ~~or~~ during heatup by nonnuclear means or cooldown following shutdown, as applicable, the reactor vessel metal and fluid temperatures shall be at or above the temperatures shown on the limiting curves of Figures 3.6.1.a or 3.6.1.b. This specification applies when the reactor vessel head is tensioned. This specification does not apply to heatup or cooldown for the purpose of performing inservice hydrostatic or leak testing.

3. The reactor vessel metal temperatures for the bottom head region and beltline region shall be at or above the temperatures shown on the limiting curves of Figure 3.6.2 during inservice hydrostatic or leak testing. The Adjusted Reference Temperature (ART) for the beltline region must be determined from the appropriate beltline curve (~~13, 18, or 21~~ 15, 18, 21, 24, or 32 EFPY) depending on the current accumulated number of effective full power years (EFPY).

4.6 Primary System Boundary

Applicability:

Applies to the periodic examination and testing requirements for the reactor cooling system.

Objective:

To determine the condition of the reactor coolant system and the operation of the safety devices related to it.

Specification:

A. Thermal and Pressurization Limitations

1. During heatups and cooldowns, the following temperatures shall be permanently logged at least every 15 minutes until the difference between any two readings taken over a 45 minute period is less than 50°F.

a. Bottom head drain.

b. Recirculation loops A and B.

2. Reactor vessel temperature and reactor coolant pressure shall be permanently logged at least every 15 minutes whenever the shell temperature is below 220°F and the reactor vessel is not vented.

3. Test specimens of the reactor vessel base, weld and heat affected zone metal subjected to the highest fluence of greater than 1 Mev neutrons shall be installed in the reactor vessel adjacent to the vessel wall at the core midplane level. The specimens and sample program shall conform to ASTM E 185-73 to the degree possible.

USAR,

As described in the ~~safety analysis report~~, detailed stress analyses have been made on the reactor vessel for both steady-state and transient conditions with respect to material fatigue. The results of these analyses are compared to allowable stress limits. Requiring the coolant temperature in an idle recirculation loop to be within 50°F of the operating loop temperature before a recirculation pump is started assures that the changes in coolant temperature at the reactor vessel nozzles and bottom head region are acceptable.

The coolant in the bottom of the vessel is at a lower temperature than that in the upper regions of the vessel when there is no recirculation flow. This colder water is forced up when recirculation pumps are started. This will not result in stresses which exceed ASME Boiler and Pressure Vessel Code, Section III limits when the temperature differential is not greater than 145°F.

The first surveillance capsule was removed at 6.8 EFPY of operation and base metal, weld metal and HAZ specimens were tested. In addition, flux wires were tested to experimentally determine the integrated neutron flux (fluence) at the surveillance capsule location. The test results are presented in General Electric Report MDE-103-0986. Measured shifts in RT_{NDT} of the base metal and weld metal were compared to predicted values per Regulatory Guide 1.99, Revision 1 which was in effect at that time. The measured values were higher than predicted, so the 1.99 methods were modified to reflect the surveillance data. The test results for the flux wires were used with analytically determined lead factors to determine the peak end-of-life (EOL) fluence at the 1/4 T Vessel wall depth. The value corresponding to 40 years operation (32 EFPY) is 1.5×10^{16} n/cm^2.

Subsequent to this evaluation, the NRC issued Regulatory Guide 1.99, Revision 2. This revision requires that two surveillance capsules be tested before the test results are factored into the adjusted reference temperature (ART) shift predictions. The adjusted reference temperature of a beltline material is defined as the initial RT_{NDT} plus the RT_{NDT} due to irradiation. Therefore, the curves developed from the initial surveillance capsule testing were re-evaluated in accordance with the guidance provided in Regulatory Guide 1.99 Revision 2. Based strictly on the chemistry factors provided in Regulatory Guide 1.99, Revision 2, and considering each beltline material chemistry and peak fluence at a given EFPY, the pressure-temperature curves in Figures 3.6.1.a and 3.6.1.b, which reflect a beltline ART of 110°F, were determined to be valid for 21 EFPY. Figure 3.6.2, the pressure test curve, was re-evaluated in like manner and includes curves for 13, 18 and 21 EFPY to provide more flexibility in pressure testing. Figure 3.6.2 also has a separate curve for the bottom head region. The bottom head curve does not shift with increased operation; therefore, the bottom head temperature can be monitored against lower temperature requirements than the beltline during pressure testing. The surveillance capsule withdrawal schedule for the remaining specimens is located in Section IV.2.7 of the CNS USAR.

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B. Coolant Chemistry

Materials in the primary system are primarily Type-304 stainless steel and Zircaloy cladding. The reactor water chemistry limits are established to provide an environment favorable to these materials. Limits are placed on conductivity and chloride concentrations. Conductivity is limited because it can be continuously and reliably measured and gives an indication of abnormal conditions and the presence of unusual materials in the coolant. Chloride limits are specified to prevent stress corrosion cracking of stainless steel.

Several investigations have shown that in neutral solutions some oxygen is required to cause stress corrosion cracking of stainless steel, while in the absence of oxygen no cracking occurs. One of these is the chloride-oxygen relationship of Williams[1], where it is shown that at high chloride concentration little oxygen is required to cause stress corrosion cracking of stainless steel, and at high oxygen concentration little chloride is required to cause cracking. These measurements were determined in a wetting and drying situation using alkaline-phosphate-treated boiler water and therefore, are of limited significance to BWR conditions. They are, however, a qualitative indication of trends.

[1]W. L. Williams, Corrosion 13, 1957, p. 539t.

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The second surveillance capsule was removed from the vessel at the end of Fuel Cycle 14, following 11.2 EFPY of operation. Based on the analysis of flux wires contained in the second capsule combined with analytically determined lead factors, the peak end-of-life (40 years of operation, or 32 EFPY) fluence at the 1/4 T vessel wall depth is predicted to be 1.1 X 10^{18} n/cm^2. Based on the testing and analysis of the base metal, weld metal, and HAZ charpy specimens removed from both the first and second surveillance capsules, new pressure-temperature curves were generated. This testing and analysis is documented in General Electric Report No. GE-NE-523-159-1292, dated February, 1993. The testing and analysis performed following the removal of the first surveillance capsule was reported in General Electric Report No. MDE-103-0986, dated May, 1987.

Figures 3.6.1.a, 3.6.1.b, and 3.6.2 reflect the results of this testing and analysis, which includes consideration of the test results obtained from the specimens removed with the first surveillance capsule. Figures 3.6.1.a and 3.6.1.b have been calculated through end-of-life, and reflect a calculated Adjusted Reference Temperature (ART) of 128°F at 32 EFPY. Figure 3.6.2 includes curves corresponding to 15, 18, 21, 24, and 32 EFPY which correspond with ARTs of 89, 96, 101, 108, and 128°F respectively, in order to provide greater flexibility during pressure testing. ← same ¶ →

APPENDIX B

3.6 Primary System Boundary

Applicability:

Applies to the operating status of the reactor coolant system.

Objective:

To assure the integrity and safe operation of the reactor coolant system.

Specification:

A. Thermal and Pressurization Limitations

1. The average rate of reactor coolant temperature change during normal heatup or cooldown shall not exceed 100°F/hr when averaged over a one-hour period.

2. During heatup by nonnuclear means or cooldown following shutdown, or during operation where the core is critical, the reactor vessel metal and fluid temperatures shall be at or above the temperatures shown on the limiting curves of Figures 3.6.1.a or 3.6.1.b as applicable. This specification applies when the reactor vessel head is tensioned. This specification does not apply to heatup or cooldown for the purpose of performing inservice hydrostatic or leak testing.

3. The reactor vessel metal temperatures for the bottom head region and beltline region shall be at or above the temperatures shown on the limiting curves of Figure 3.6.2 during inservice hydrostatic or leak testing. The Adjusted Reference Temperature (ART) for the beltline region must be determined from the appropriate beltline curve (15, 18, 21, 24, or 32 EFPY) depending on the current accumulated number of effective full power years (EFPY).

4.6 Primary System Boundary

Applicability:

Applies to the periodic examination and testing requirements for the reactor cooling system.

Objective:

To determine the condition of the reactor coolant system and the operation of the safety devices related to it.

Specification:

A. Thermal and Pressurization Limitations

1. During heatups and cooldowns, the following temperatures shall be permanently logged at least every 15 minutes until the difference between any two readings taken over a 45 minute period is less than 50°F.

a. Bottom head drain.

b. Recirculation loops A and B.

2. Reactor vessel temperature and reactor coolant pressure shall be permanently logged at least every 15 minutes whenever the shell temperature is below 220°F and the reactor vessel is not vented.

3. Test specimens of the reactor vessel base, weld and heat affected zone metal subjected to the highest fluence of greater than 1 Mev neutrons shall be installed in the reactor vessel adjacent to the vessel wall at the core midplane level. The specimens and sample program shall conform to ASTM E 185-73 to the degree possible.

As described in the USAR, detailed stress analyses have been made on the reactor vessel for both steady-state and transient conditions with respect to material fatigue. The results of these analyses are compared to allowable stress limits. Requiring the coolant temperature in an idle recirculation loop to be within 50°F of the operating loop temperature before a recirculation pump is started assures that the changes in coolant temperature at the reactor vessel nozzles and bottom head region are acceptable.

The coolant in the bottom of the vessel is at a lower temperature than that in the upper regions of the vessel when there is no recirculation flow. This colder water is forced up when recirculation pumps are started. This will not result in stresses which exceed ASME Boiler and Pressure Vessel Code, Section III limits when the temperature differential is not greater than 145°F.

The second surveillance capsule was removed from the vessel at the end of Fuel Cycle 14, following 11.2 EFPY of operation. Based on the analysis of flux wires contained in the second capsule combined with analytically determined lead factors, the peak end-of-life (40 years of operation, or 32 EFPY) fluence at the 1/4 T vessel wall depth is predicted to be 1.1×10^{18} n/cm^2. Based on the testing and analysis of the base metal, weld metal, and HAZ charpy specimens removed from both the first and second surveillance capsules, new pressure-temperature curves were generated. This testing and analysis is documented in General Electric Report No. GE-NE-523-159-1292, dated February, 1993. The testing and analysis performed following removal of the first surveillance capsule was reported in General Electric Report No. MDE-103-0986, dated May, 1987.

Figures 3.6.1.a, 3.6.1.b, and 3.6.2 reflect the results of this testing and analysis, which includes consideration of the test results obtained from the specimens removed with the first surveillance capsule. Figures 3.6.1.a and 3.6.1.b have been calculated through end-of-life, and reflect a calculated Adjusted Reference Temperature (ART) of 128°F at 32 EFPY. Figure 3.6.2 includes curves corresponding to 15, 18, 21, 24, and 32 EFPY which correspond with ARTs of 89, 96, 101, 108, and 128°F respectively, in order to provide greater flexibility during pressure testing. Figure 3.6.2 also has a separate curve for the bottom head region. The bottom head curve does not shift with increased operation; therefore, the bottom head temperature can be monitored against lower temperature requirements than the beltline during pressure testing. The surveillance capsule withdrawal schedule for the remaining specimens is located in Section IV.2.7 of the CNS USAR.

B. Coolant Chemistry

Materials in the primary system are primarily Type-304 stainless steel and Ziracloy cladding. The reactor water chemistry limits are established to provide an environment favorable to these materials. Limits are placed on conductivity and chloride concentrations. Conductivity is limited because it can be continuously and reliably measured and gives an indication of abnormal conditions and the presence of unusual materials in the coolant. Chloride limits are specified to prevent stress corrosion cracking of stainless steel.

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[1]W. L. Williams, Corrosion 13, 1957, p. 539t.

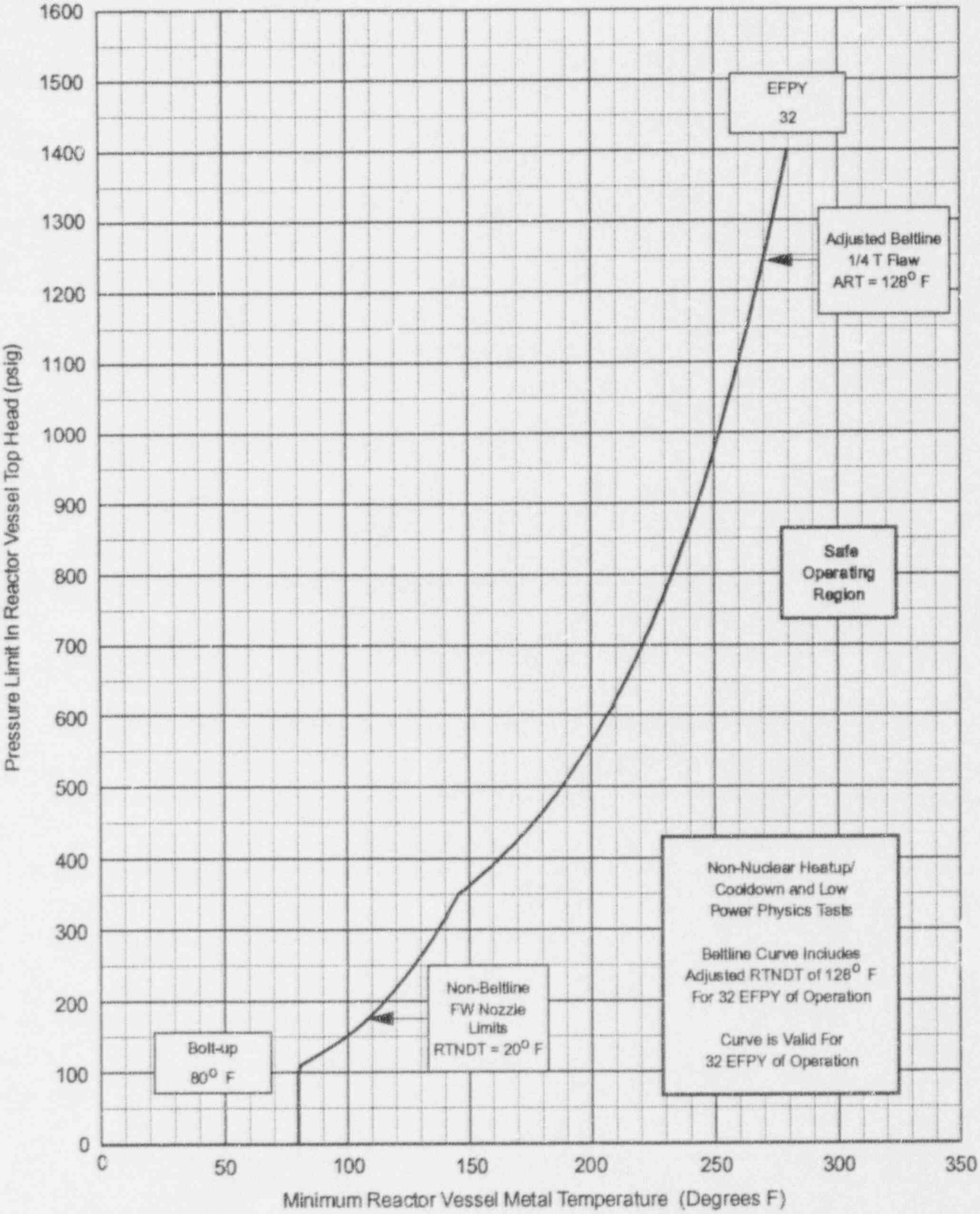

Figure 3.6.1.a Minimum Temperature for Non-Nuclear Heatup/Cooldown

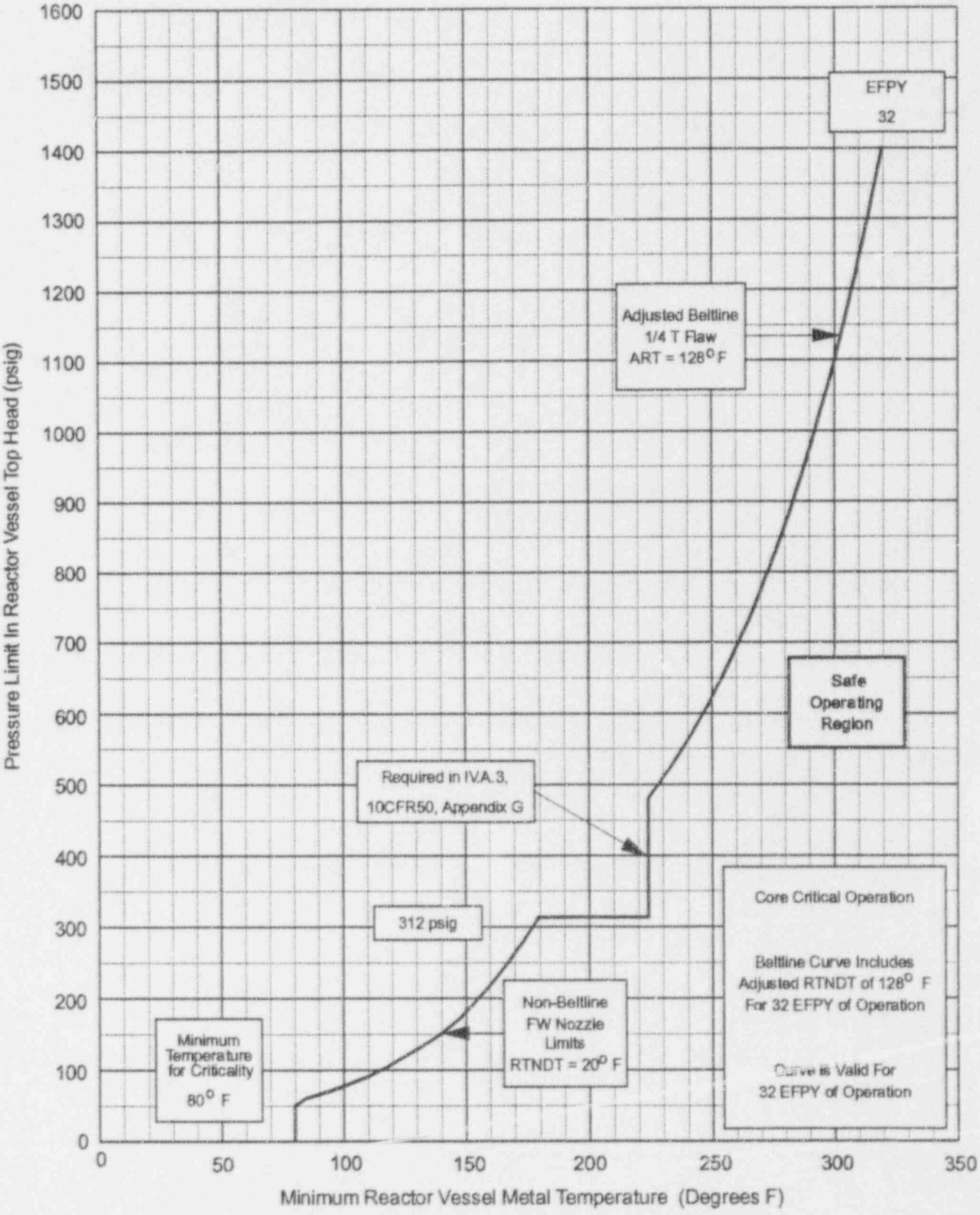

Figure 3.6.1.b Minimum Temperature for Core Critical Operation

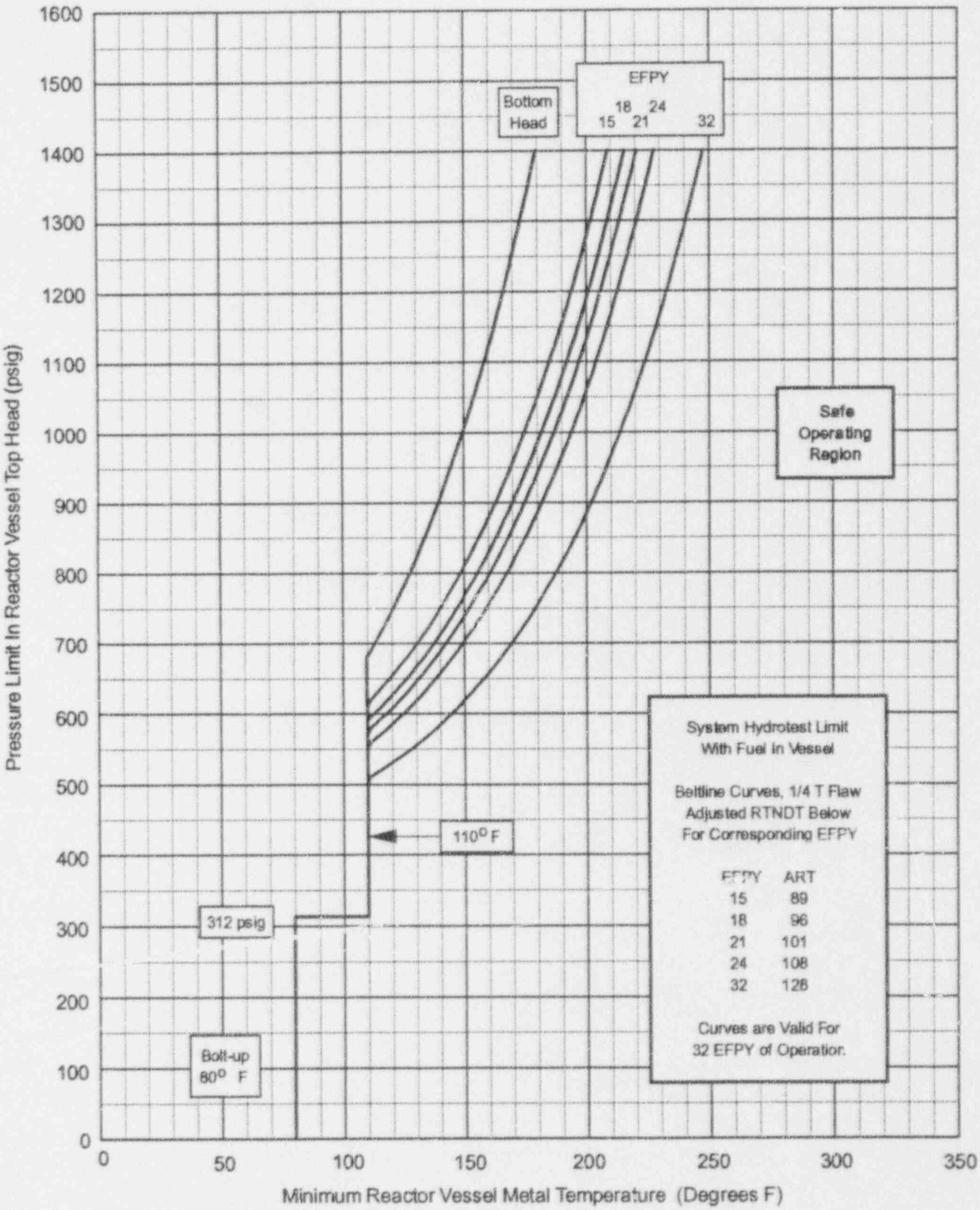

Figure 3.6.2 Minimum Temperature for Pressure Tests