June 3, 2003

Mr. Charles Slade
Room 320
917 Main St.
Vancouver, British Columbia
Canada V6A2V8

SUBJECT: STRESS CORROSION CRACKING FORMULA

Dear Mr. Slade:

I am responding to your letter of May 5, 2003, to the Nuclear Regulatory Commission (NRC) in which you requested information on the formula for stress corrosion cracking in nuclear reactors.

Stress corrosion cracking has occurred in various materials used to fabricate nuclear reactor components, including austenitic stainless steels and nickel-based alloys. With the recent attention to cracking of nickel-based alloys, I assume that you are interested in the formula for stress corrosion cracking of thick section Alloy 600 base materials.

Stress corrosion cracking in nickel-based alloys, including Alloy 600 base material and weld filler metals Alloy 82 and 182, has predominately occurred in steam generator tubing, reactor vessel head penetration nozzles, reactor coolant system piping and welds. Resources for specific information on each of these areas are located at the Nuclear Regulatory Commissions' Public Web Site. The following site addresses may be of some assistance:

- Generic Activities on Alloy 600 Cracking
  http://www.nrc.gov/reactors/operating/ops-experience/alloy600.html

- Steam Generator Action Plan
  http://www.nrc.gov/reactors/operating/ops-experience/steam-generator-tube.html

For thick section Alloy 600 base metal, a recent NRC letter (April 11, 2003 letter from R. Barrett to A. Marion, NEI—ML030980322 and ML030980333—enclosed for your information and convenience) provides the following formula as a part of interim guidance on evaluation of flaws identified in vessel head penetration nozzles:

$$\dot{a} = \exp\left[-\frac{Q_g}{R}\left(\frac{1}{T}-\frac{1}{T_{ref}}\right)\right]\alpha\left(K_I - K_{th}\right)^{\beta}$$

Where:

$\dot{a}$ = crack growth rate at temperature T in m/s

Q_g = thermal activation energy for crack growth
= 130 kJ/mole

R = universal gas constant
= 8.314×10^{-3} kJ/mole °K

T = absolute operating temperature at location of crack, °K

T_{ref} = absolute reference temperature used to normalize data
= 598.15 °K

α = crack growth rate coefficient
= 2.67×10^{-12} at 325 °C for $\dot{a}$ in units of m/s and K_I in units of $MPa\sqrt{m}$

K_I = crack tip stress intensity factor, $MPa\sqrt{m}$

K_{th} = crack tip stress intensity factor threshold for primary water stress corrosion cracking of Alloy 600
= 9 $MPa\sqrt{m}$

β = exponent
= 1.16

This formula is described in detail in report MRP-55, which can be accessed at: http://www.nrc.gov/reactors/operating/ops-experience/alloy600/alloy600-files/08-14-02-mrp-55-report.pdf. Although the NRC has performed a preliminary review of MRP-55 to the extent that the above crack growth formula can be used in the interim, please note that the NRC has not completed its review of MRP-55.

The following two resources may be of interest regarding stress corrosion cracking of reactor vessel head penetrations.

- Non-Proprietary Version of the Staff Preliminary Technical Assessment of Reactor Pressure Vessel Head Penetration Nozzle Cracking http://www.nrc.gov/reactors/operating/ops-experience/alloy600/alloy600-files/ml013460610.pdf

- Evaluation of Flaws in PWR Reactor Vessel Upper Head Penetration Nozzles http://www.nrc.gov/reactors/operating/ops-experience/vessel-head-degradation/vessel-head-degradation-files/04-11-03-flaw-evaluation-app-a-ml0309803330.pdf

If you do not have Internet access, documents may be examined, and/or copied for a fee, at the NRC's Public Document Room (PDR), located at One White Flint North, 11555 Rockville Pike (first floor), Rockville, Maryland, 20852. For requests please contact the NRC PDR Reference staff by telephone at 1-800-397-4209 or 301-415-4737.

I trust this information answers your question. If you have additional questions regarding this matter please contact Mr. Jay Collins of my staff by e-mail, jxc@nrc.gov, or telephone, (301) 415-4038.

Sincerely,

/RA by Christopher I. Grimes Acting For/

Dr. Richard J. Barrett, Director
Division of Engineering
Office of Nuclear Reactor Regulation
United States Nuclear Regulatory Commission

Enclosure: As stated

- Evaluation of Flaws in PWR Reactor Vessel Upper Head Penetration Nozzles http://www.nrc.gov/reactors/operating/ops-experience/vessel-head-degradation/vessel-head-degradation-files/04-11-03-flaw-evaluation-app-a-ml0309803330.pdf

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Sincerely,

Dr. Richard J. Barrett, Director
Division of Engineering
Office of Nuclear Reactor Regulation
United States Nuclear Regulatory Commission

Enclosure: As stated

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Enclosure

April 11, 2003 Letter
from R. Barrett to
A. Marion of the Nuclear Energy Institute
ML030980322 and ML030980333