bc: LER Distribution List, C. Trammell, M. Axelrad, LIS,
TNP:GOV REL F:NRC Chrono, PGE to IE,
TNP:GOV REL F:NRC LICENSEE EVENT REPORT

Portland General Electric Company

Donald J. Broehl Assistant Vice President

January 18, 1979

Trojan Nuclear Plant
Docket 50-344
License NPF-1

Director of Nuclear Reactor Regulation
ATTN: Mr. A. Schwencer, Chief
Operating Reactors Branch #1
Division of Operating Reactors
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Sir:

As indicated in our response dated December 31, 1979 to NRC Staff Question 1a of December 29, 1979 regarding LER 79-15, attached is confirmatory information regarding stresses in walls due to thermal gradients. This completes our response to NRC Staff Question 1.

Sincerely,

/s/ D. J. Broehl

DBJ/LWE/4sa3A4
Attachment

c: Mr. R. H. Engelken, Director
U. S. Nuclear Regulatory Commission
Region V

Mr. Lynn Frank, Director
State of Oregon
Department of Energy

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SHEAR STRESSES DUE TO THERMAL GRADIENTS

When a reinforced grouted masonry wall is subjected to a thermal gradient across its thickness, it undergoes a deformation. In the unrestrained state the wall may assume curvatures in two directions. To the extent that such curvatures are restrained, the wall will be subjected to bending moments and possible transverse shear forces. For example, if constraints to the rotation at the top and bottom of a wall height are considered to be offered by the supporting floor slabs, restraining moments will develop in the wall at these supports and in the symmetrical condition, the moment will remain constant throughout the height of the wall. This condition will, therefore, not develop any transverse shear forces in the wall. However, in the case of a wall having more than two supports, especially in the end span, if a conservative assumption is made that moment at one end is zero, the transverse shear will be equal to the moment at the continuous end divided by the wall span. Therefore, a conservative assessment of shear stress in the wall can be made by assuming the wall modeled as a beam of unit width fixed at one end and simply supported at the other end, and subjected to a through wall temperature difference Δt.

Loading Conditions

For the purpose of evaluating the interface shear stress (VQ/Ib) in a wall section, two different loading conditions will be considered: (a) the wall is subjected to a temperature gradient only and no other loads, and (b) the wall is subjected to real

loads, such as its own inertia load, in combination with the thermal gradient. In the case of a thermal gradient alone, the wall will be assumed to act as an uncracked homogeneous section with the neutral axis at the geometric centroid of the section, until the modulus of rupture is exceeded at the tension face. When the tensile stress is more than the modulus of rupture, a crack will be assumed to form resulting in a shift in the neutral axis towards the compression zone and the moment will correspondingly decrease without much increase in displacement. This will also be the case when the real loads act on the wall developing a cracked condition.

The following two bounding cases are, therefore, considered to evaluate the wall's shear stresses:

(i) Thermal Shear Stress corresponding to cracking moment, M_c
(ii) Thermal Shear Stress corresponding to cracked analysis.

Shear Stress Corresponding to M_c

Assuming a modulus of rupture of the concrete block wall of 200 psi (based on 0.1 x mortar strength),

$$M_c = 200 \frac{bt^2}{6}$$

$$= 33.3\ bt^2$$

$$V = \frac{M_c}{\ell}$$

$$= 33.3 \frac{bt^2}{\ell}$$

Shear Stresses Due to Thermal Gradients

where, M_c = Cracking moment, inch-lbs/ft
V = Transverse shear force, lbs, t
b = Width of section
t = Thickness of wall, inches
ℓ = Height of wall, inches
τ_{max} = Maximum shear stress, psi

Case (i)

t = 16" (double wythe wall)

ℓ = 16' = 192"

$$\tau_{max} = \frac{1.5V}{A}$$

$$= 50\frac{t}{\ell}$$

$$= 50 \times \frac{16}{192}$$

$$= 4.17 \text{ psi}$$

Case (ii)

t = 30" (composite wall)

Shear at block-concrete interface,

$$\tau = \frac{VQ}{Ib} \text{ (where, } Q = (12)(8)(11) = 1056 \text{ in}^3 \text{ ; } I = \frac{12(30)^3}{12} = 27{,}000 \text{ in}^4\text{)}$$

$$= \frac{(33.33)(12)(30)^2(1056)}{(27{,}000)(12)(192)}$$

$$= 6.1 \text{ psi}$$

Shear Stresses Due to Thermal Gradients

Temperature Gradient to Develop M_c

E_c = Modulus of Elasticity of grouted block, psi
= 2.64×10^6 psi*

α = Coefficient of thermal expansion
= 6.0×10^{-6} inch/inch/°F

Δt = Temperature difference, °F

σ_c = Cracking stress (Modulus of rupture), psi

n = Modular ratio

$$= \frac{E_s}{E_c} = \frac{30}{2.64}$$

$$= 11.36$$

$$\sigma_c = \frac{\Delta t \alpha E}{2}$$

or, $$\Delta t = \frac{2\sigma_c}{\alpha E}$$

$$= \frac{2 \times 200}{6 \times 2.64}$$

$$\Delta t = 25.3°F$$

Hence, cracking will develop in the walls when the temperature gradient, Δt, across their thicknesses reaches 25°F.

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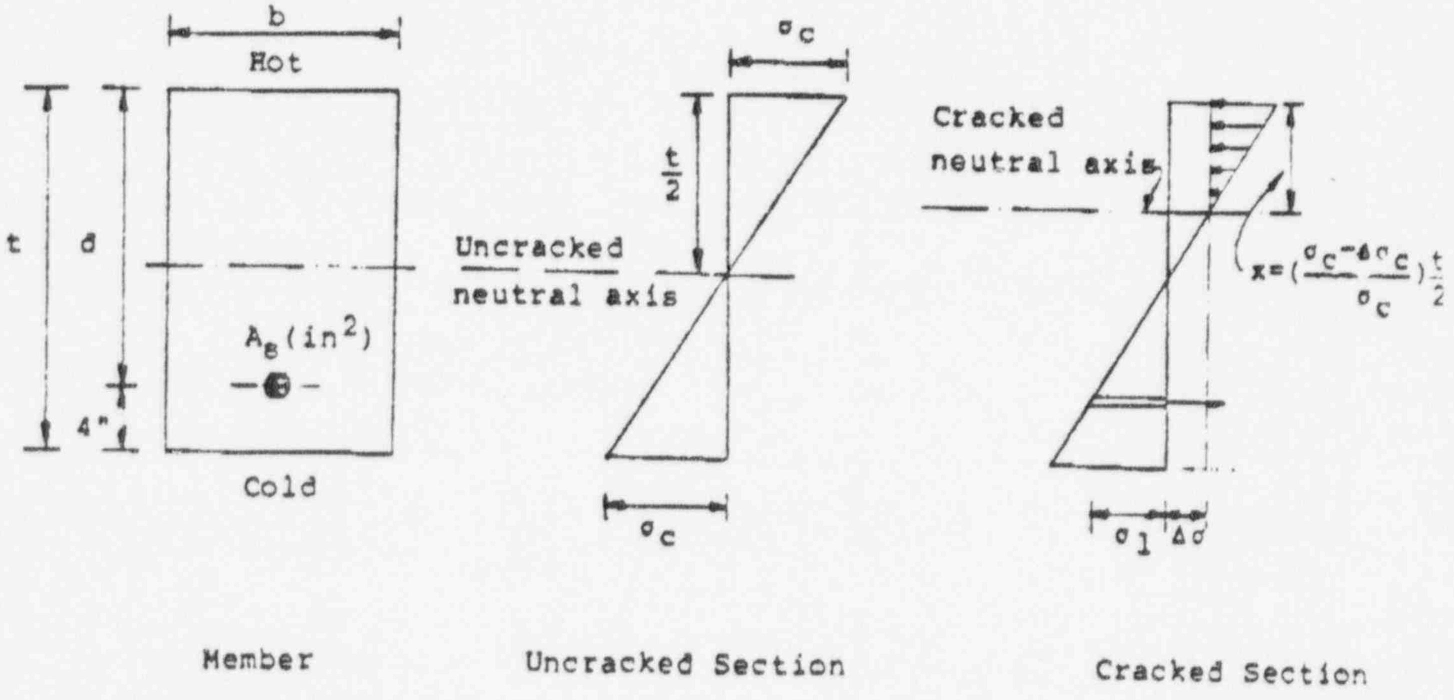
* Value of E_c has been taken as an average of the block and grout modulii.

Shear Stresses Due to Thermal Gradients

Shear Stress in Wall Section Considering Cracking

For the purpose of this evaluation, a thermal gradient, Δt, of 50°F is assumed, although there are only a few exterior walls in the Complex, e.g. the walls enclosing thermostatically controlled areas such as the Control Room and the office area, where such a gradient may be reached.



$$\sigma_c = \frac{\Delta t}{2}\alpha E$$

$$= \frac{50}{2}(6 \times 2.64)$$

$$= 396 \text{ psi}$$

Shear Stresses Due to Thermal Gradients

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From force equilibrium,

$$A_s f_s \quad - \frac{\sigma_c}{2}\left(\frac{t}{2}\right)b \quad + \frac{\Delta\sigma b}{2}\left[\frac{t}{2} + \frac{t}{2}\left(\frac{\sigma_c - \Delta\sigma}{\sigma_c}\right)\right] = 0 \text{ ......(1)}$$

Reinforcing tension	Initial concrete compression force	Reduction in concrete compression

Case 1

t = 16 inches (double wythe section)

A_s = #6 @ 16" o.c.

= 0.33 in^2/ft

$$\sigma_1 = \frac{(t/2) - (4)}{t/2}\sigma_c$$

$$= \frac{8 - 4}{8}(396)$$

= 198 psi

∴ From equation (1),

$$0.33(198 + \Delta\sigma)(11.36) - \frac{396}{2}(8)(12) + \frac{\Delta\sigma(12)}{2}\left[8 + 8\left(\frac{396 - \Delta\sigma}{396}\right)\right] = 0$$

Or, $\Delta\sigma$ = 272 psi

Shear Stresses Due to Thermal Gradients

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$$f_s = (\sigma_1 + \Delta\sigma)n$$
$$= (198 + 272)(11.36)$$
$$= 5.34 \text{ ksi}$$

$$x = [\frac{\sigma_c - \Delta\sigma}{\sigma_c}]\frac{t}{2}$$
$$= \frac{396 - 272}{396} \times \frac{16}{2}$$
$$= 2.51"$$

$$M = A_s f_s (d - \frac{x}{3})$$
$$= (0.33)(5340)(12 - \frac{2.51}{3})$$
$$= 19{,}675 \text{ inch-lbs/ft}$$

$$V = \frac{M}{\ell}$$

$$\tau_{max} = \frac{1.5V}{A}$$
$$= \frac{(1.5)(19{,}675)}{(12 \times 16)(192)}$$
$$= 0.80 \text{ psi}$$

<u>Shear Stresses Due to Thermal Gradients</u>

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<u>Case 2</u>

$t = 30$ inches (composite wall)

$A_s = \#6 @ 24"$ o.c.

$= 0.22\ in^2/ft$

$$\sigma_1 = \frac{(t/2) - (4)}{t/2}\sigma_c$$

$$= \frac{15 - 4}{15}(396)$$

$= 290$ psi

.'. From equation (1),

$$0.33(290 + \Delta\sigma)(11.36) = \frac{396}{2}(15)(12) + \frac{\Delta\sigma(12)}{2}[15 + 15(\frac{396-\Delta\sigma}{396})]$$

Or, $\Delta\sigma = 315$ psi

$$f_s = (\sigma_1 + \Delta\sigma)n$$
$$= (290 + 315)(11.36)$$
$$= 6.87 \text{ ksi}$$

$$x = (\frac{\sigma_c - \Delta\sigma}{\sigma_c})\frac{t}{2}$$

$$= \frac{396 - 315}{396}(15)$$

$= 3.07"$

$$M = A_s f_s (d - \frac{x}{3})$$

$$= (0.22)(6870)(26 - 1.02)$$

$= 37,767$ inch-lbs/ft

Shear Stresses Due to Thermal Gradients

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$$V = \frac{M}{\ell}$$

$$\tau_{max} = \frac{(1.5)(37,767)}{(30 \times 12)(192)}$$

$$= 0.82 \text{ psi}$$

The above evaluations show that although the thermal gradient acting alone can cause a shear stress of approximately 4 to 6 psi in an uncracked exterior wall (both double wythe and composite), when the temperature acts in conjunction with the real loads, the cracking condition in the wall section will ensue and the consequent shear stress will decrease to approximately 0.80 to 1.0 psi.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	Docket 50-344
PORTLAND GENERAL ELECTRIC COMPANY, et al	)	(Control Building Proceeding)
	)	
(Trojan Nuclear Plant)	)	

CERTIFICATE OF SERVICE

I hereby certify that on January 18, 1980, Licensee's letter to the Director of Nuclear Reactor Regulation with additional information relative to LER 79-15 has been served upon the persons listed below by depositing copies thereof in the United States mail with proper postage affixed for first class mail.

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Dated: January 18, 1980

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