Table 401-3.4.2-1 Service Temperature Limits for Repair Systems

<table>
<thead>
<tr>
<th>Property Measurement</th>
<th>Substrate Leaking, $T_m$</th>
<th>Substrate Not Leaking, $T_m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_g$</td>
<td>$T_g$ - 30°C (54°F)</td>
<td>$T_g$ - 20°C (36°F)</td>
</tr>
<tr>
<td>HDT</td>
<td>HDT - 25°C (45°F)</td>
<td>HDT - 15°C (27°F)</td>
</tr>
</tbody>
</table>

(Temperatures in Celsius)

$$f_T = 6 \times 10^{-5}(T_m - T_d)^2 + 0.001(T_m - T_d) + 0.7014$$  \hspace{1cm} (1)

(Temperatures in Fahrenheit)

$$f_T = 2 \times 10^{-5}(T_m - T_d)^2 + 0.0006(T_m - T_d) + 0.7014$$  \hspace{1cm} (2)

The maximum allowable value of $f_T$ is 1.

401-3.4.3 Component Allowable Stress. Use of the design method in this section is appropriate if the contribution of the component is to be included in the calculation for load-carrying capability.

401-3.4.3.1 Underlying Substrate Does Not Yield

(a) In the derivation of eqs. (3) and (4), it is assumed that the underlying substrate does not yield.

(b) For hoop stresses due to internal pressure, the minimum repair laminate thickness, $t_{\text{min}}$, is given by

$$t_{\text{min}} = \frac{D}{2s} \left( \frac{E_s}{E_c} \right) \left( P - P_s \right)$$  \hspace{1cm} (3)

(c) For axial stresses due to internal pressure, bending, and axial thrust, the minimum repair laminate thickness, $t_{\text{min}}$, is given by

$$t_{\text{min}} = \frac{D}{2s} \left( \frac{E_s}{E_c} \right) \left( \frac{2F}{\pi D^2} - P_s \right)$$  \hspace{1cm} (4)

(d) The design repair laminate thickness, $t_{\text{repair}}$, shall be the greater value determined from eqs. (3) and (4).

(e) Where the purpose of the repair system is to strengthen an undamaged section of the component to carry additional bending or other axial loads, the value of $F$ shall be the increased total axial load requirement and the value of $P_s$ shall be the original MAWP/MAOP/MOP. The value of $F$ depends on the specific application details and shall be considered by the repair system designer (outside the scope of this Article).

401-3.4.3.2 Underlying Substrate Yields

(a) In the derivation of eqs. (5) and (6) it is assumed that the composite does not yield and the repair laminate is designed based on the allowable strain of the composite. Only hoop loading shall be considered in determining the design repair laminate thickness, $t_{\text{repair}}$.

(b) For hoop strain due to internal pressure, the design repair laminate thickness, $t_{\text{repair}}$, may be calculated by iteration using

$$\epsilon_c = \frac{PD}{2E_t t_{\text{min}}} - t_s - \frac{P_{\text{live}} D}{2(E_t t_{\text{min}} + E_s t_s)}$$  \hspace{1cm} (5)

(c) If the repair is applied at zero internal pressure, i.e., $P_{\text{live}} = 0$, then eq. (5) can be rearranged to give

$$t_{\text{min}} = \frac{1}{\epsilon_c E_t} \left( \frac{PD}{2} - t_s \right)$$  \hspace{1cm} (6)

(d) The assumptions made in deriving eqs. (5) and (6) are that the substrate material is elastic and perfectly plastic (i.e., no strain hardening), and that no defect assessment is performed other than use of the minimum remaining wall thickness (of the substrate) to infer the internal pressure at the point of substrate yield.

(e) The value of the allowable strain of the composite in the circumferential direction can be taken from eqs. (10a) and (10b) or if performance data are available, from Mandatory Appendix 401-V. The appropriate service factor is taken from Table 401-3.4.5-1.

(f) For axial loads in pipelines, eq. (7) shall be utilized.

$$t_{\text{min}} = \frac{1}{\epsilon_a E_c} \left( \frac{PD}{4} - t_s \right)$$  \hspace{1cm} (7)

where $t_s$ may be conservatively the minimum wall thickness or the equivalent remaining wall thickness based on the defect assessment.

401-3.4.4 Repair Laminate Allowable Strains

(a) Use of the design method in this section is appropriate if the contribution of the original component is to be excluded in the calculation for load-carrying capability and if short-term material properties are to be used.

(b) The allowable repair laminate strain design method is a function of design temperature.

(c) For hoop stresses due to internal pressure, the minimum repair laminate thickness, $t_{\text{min}}$, is given by

$$t_{\text{min}} = \frac{1}{\epsilon_c} \left( \frac{PD}{2 E_c} - \frac{F_{\text{req}}}{\pi D} \right)$$  \hspace{1cm} (8)

(d) For axial stresses due to internal pressure, bending, and axial thrust, the minimum repair laminate thickness, $t_{\text{min}}$, is given by
Table 1  Repair System Required Material and Performance Properties

<table>
<thead>
<tr>
<th>Material Property</th>
<th>International Test Method</th>
<th>ASTM Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>ISO 527</td>
<td>ASTM D 3039</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>ISO 527</td>
<td>ASTM D 3039</td>
</tr>
<tr>
<td>Shear modulus (in-plane)</td>
<td></td>
<td>ASTM D 5379</td>
</tr>
<tr>
<td>Thermal expansion coefficients</td>
<td>ISO 11359-2</td>
<td>ASTM E 831</td>
</tr>
<tr>
<td>Glass transition temperature of resin, T_g, or HDT</td>
<td>ISO 11357-2 or ISO 75</td>
<td>ASTM D 6604, ASTM E 1640, or ASTM E 831</td>
</tr>
<tr>
<td>Barcol or Shore hardness</td>
<td>BS EN 59, ISO 868</td>
<td>ASTM D 2583</td>
</tr>
<tr>
<td>Bending modulus</td>
<td>ISO 178</td>
<td>ASTM D 790</td>
</tr>
<tr>
<td>Adhesion strength</td>
<td>Lap shear</td>
<td>ASTM D 3165</td>
</tr>
<tr>
<td>Performance data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-term strength (optional)</td>
<td>Appendix V</td>
<td></td>
</tr>
<tr>
<td>Energy release rate (optional)</td>
<td>Appendix IV</td>
<td></td>
</tr>
<tr>
<td>Structural strengthening (optional)</td>
<td>Appendix III</td>
<td></td>
</tr>
</tbody>
</table>

Table 2  Service Upper Temperature Limits for Repair Systems

<table>
<thead>
<tr>
<th>Substrate Leaking, T_g</th>
<th>Substrate Not Leaking, T_m</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_g = 30°C (54°F)</td>
<td>T_m = 20°C (68°F)</td>
</tr>
<tr>
<td>T_g can be measured</td>
<td>T_m cannot be measured</td>
</tr>
<tr>
<td>T_g = 30°C (54°F)</td>
<td>T_m = 20°C (68°F)</td>
</tr>
<tr>
<td>T_g cannot be measured</td>
<td>HDT = 20°C (36°F)</td>
</tr>
<tr>
<td>HDT = 20°C (36°F)</td>
<td>HDT = 15°C (27°C)</td>
</tr>
</tbody>
</table>

Table 3  Factors for Elevated Temperatures

<table>
<thead>
<tr>
<th>Temperature, °C</th>
<th>Temperature, °F</th>
<th>Temperature Factor, f_t</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_g = T_m</td>
<td>120°F</td>
<td>0.7</td>
</tr>
<tr>
<td>T_g = T_m - 20</td>
<td>100°F</td>
<td>0.75</td>
</tr>
<tr>
<td>T_g = T_m - 40</td>
<td>80°F</td>
<td>0.85</td>
</tr>
<tr>
<td>T_g = T_m - 50</td>
<td>60°F</td>
<td>0.9</td>
</tr>
<tr>
<td>T_g ≤ T_m - 60</td>
<td>40°F</td>
<td>1</td>
</tr>
</tbody>
</table>

\[ t_{\text{min}} = \frac{D}{2s} \left( \frac{E_s}{E_c} \right) \left( \frac{2F}{\pi D^2} - P_s \right) \]  

For hoop strain due to internal pressure, the design repair laminate thickness, \( t_{\text{repair}} \), may be calculated by iteration using

\[ \epsilon_c = \frac{PD}{2E_c t_{\text{repair}}} - \frac{t_s}{E_c t_{\text{repair}}} - \frac{P_{\text{live}}D}{2(E_c t_{\text{repair}} + E_d t_d)} \]  

(3)

If the repair is applied at zero internal pressure, i.e., \( P_{\text{live}} = 0 \), then eq. (3) can be rearranged to give

\[ t_{\text{repair}} = \frac{1}{\epsilon_c} \left( \frac{PD}{2} - s t_s \right) \]  

(4)

The assumptions made in deriving eqs. (3) and (4) are that the substrate material is elastic, perfectly plastic, i.e., no strain hardening and that no defect assessment is performed other than use of the minimum remaining wall thickness (of the substrate) to infer the internal pressure at the point of substrate yield.

The value of the allowable strain of the composite in the circumferential direction can be taken from eq. (7) or if performance data are available, from Appendix V. The appropriate service factor is taken from Table 5.

3.4.4 Repair Laminate Allowable Strains. Use of the design method in this section is appropriate if the contribution of the original pipe is to be ignored in the calculation for load-carrying capability and if short-term material properties are to be used.

The allowable repair laminate strain design method is a function of design temperature.

For hoop stresses due to internal pressure, the minimum repair laminate thickness, \( t_{\text{min}} \), is given by

\[ t_{\text{min}} = \frac{1}{\epsilon_c} \left( \frac{PD}{2} \frac{1}{E_c} - \frac{F}{\pi D E_c} \right) \]  

(5)

The design repair laminate thickness, \( t_{\text{repair}} \), shall be the greater value determined from eqs. (1) and (2).

Where the purpose of the Repair System is to strengthen an undamaged section of pipe to carry additional bending or other axial loads, the value of \( F \) shall be taken to be the increased total axial load requirement and the value of \( P_s \) shall be the original MAWP.

For pipelines, eq. (3) or (4) shall be used. In the derivation of eqs. (3) and (4) it is assumed that the underlying substrate does yield and the repair laminate is designed based on the allowable strain of the composite. Only hoop loading is considered in determining the design repair laminate thickness.
is performed other than use of the minimum remaining wall thickness (of the substrate) to infer the internal pressure at the point of substrate yield.

The value of the allowable strain of the composite in the circumferential direction can be taken from eq. (9) or if performance data are available, from Mandatory Appendix V. The appropriate service factor is taken from Table 4.

3.4.4 Repair Laminate Allowable Strains. Use of the design method in this section is appropriate if the contribution of the original pipe is to be ignored in the calculation for load-carrying capability and if short-term material properties are to be used.

The allowable repair laminate strain design method is a function of design temperature.

For hoop stresses due to internal pressure, the minimum repair laminate thickness, $t_{\text{min}}$, is given by

$$t_{\text{min}} = \frac{PD}{2}\left(\frac{1}{E_c} - \frac{F}{\pi D E_c}\right)$$

For axial stresses due to internal pressure, bending, and axial thrust, the minimum repair laminate thickness, $t_{\text{min}}$, is given by

$$t_{\text{min}} = \frac{F}{\pi D E_c} - \frac{PD}{2}\left(\frac{1}{E_c} - \frac{F}{\pi D E_c}\right)$$

The design repair laminate thickness, $t_{\text{repair}}$, shall be the greater value determined from eqs. (7) and (8).

Rarely occurring events (e.g., pressure excursions above design pressure) may be assessed using the strains given in Table 3, provided that they occur typically less than 10 times in the life of the component with each duration less than 30 min.

The continuous (sustained) long-term allowable strains listed in Table 3 shall only be used if the short-term tensile strain to failure of the repair laminate is at least 1%, otherwise performance data derived according to para. 3.4.5 shall be used. The short-term strain to failure shall be derived from the test carried out to determine the tensile properties of the laminate (Table 1).

Some Repair System suppliers may choose to use laminate analysis to calculate modulus values for laminates built up from a series of different layers. This is satisfactory, provided that the results from the laminate analysis have been validated using measured data.

### Table 3 Allowable (Long Term) Strains for Repair Laminates (No Allowance for Temperature Effects)

<table>
<thead>
<tr>
<th>Load Type</th>
<th>Symbol</th>
<th>Rarely Occurring, %</th>
<th>Continuous (Sustained), %</th>
</tr>
</thead>
<tbody>
<tr>
<td>For $E_c &gt; 0.5 E_c$</td>
<td>$\varepsilon_{0a}$</td>
<td>0.40</td>
<td>0.25</td>
</tr>
<tr>
<td>For $E_c &lt; 0.5 E_c$</td>
<td>$\varepsilon_{0a}$</td>
<td>0.40</td>
<td>0.25</td>
</tr>
<tr>
<td>Circumferential</td>
<td>$\varepsilon_{0a}$</td>
<td>0.40</td>
<td>0.25</td>
</tr>
<tr>
<td>Axial</td>
<td>$\varepsilon_{0a}$</td>
<td>0.25</td>
<td>0.10</td>
</tr>
</tbody>
</table>

### Table 4 Service Factors for Repair Laminates

<table>
<thead>
<tr>
<th>Test</th>
<th>Service Factor, $f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000 hr data</td>
<td>0.5</td>
</tr>
<tr>
<td>Design life data</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Thermal expansion coefficients for composite Repair Systems are different than those for the substrate, so thermal stresses will be generated where operating temperatures vary from installation temperature. Where this absolute temperature change is greater than 40°C (72°F), the effect of differential thermal expansion between the repair laminate and the substrate shall be considered in the design assessment.

The allowable repair laminate strains (circumferential and axial) shall be calculated by

$$\varepsilon_i = f_y \varepsilon_{0a} - \Delta T (\alpha_i - \alpha_c)$$

where $\varepsilon_{0a}$ and $\varepsilon_{0a}$ are from Table 3.

3.4.5 Repair Laminate Allowable Stresses Determined by Performance Testing. Use of the design method in this section is appropriate if performance-based test data are available.

Mandatory Appendix V provides three alternative methods for the determination of long-term failure stress (or strain).

If allowance for pipe is not to be included, then eq. (10) shall be used.

For hoop stresses due to internal pressure, the minimum repair laminate thickness, $t_{\text{min}}$, is given by

$$t_{\text{min}} = \frac{PD}{2f_{\text{st}}^{1.5}}$$

For axial stresses due to internal pressure, bending, and axial thrust, the minimum repair laminate thickness, $t_{\text{min}}$, is given by eq. (4) or (8), as appropriate.

The design repair laminate thickness, $t_{\text{repair}}$, shall be the greater of the values determined.

If allowance for the pipe is to be included, then eq. (11) shall be used.

For hoop stresses due to internal pressure, the design repair laminate thickness, $t_{\text{repair}}$, is given by

$$t_{\text{repair}} = \left(\frac{PD}{2} - t_8\right) \cdot \left(\frac{1}{f_{\text{st}}^{1.5}}\right)$$

The service factor, $f$, is the lesser of that obtained from Table 4 and from the appropriate construction code.

3.4.6 Leaking Pipes and Vessels. A (substrate) pipe or vessel shall be considered to be leaking if the wall thickness at any point of the affected area is determined to be less than 1 mm (0.04 in.) at the end of its life.
(b) For hoop stresses due to internal pressure, the minimum repair laminate thickness, $t_{min}$, is given by

$$t_{min} = \frac{D}{2s} \cdot \frac{E_t}{E_p} \cdot (P - P_t) \quad (3)$$

(c) For axial stresses due to internal pressure, bending, and axial thrust, the minimum repair laminate thickness, $t_{min}$, is given by

$$t_{min} = \frac{D}{2s} \cdot \frac{E_t}{E_p} \cdot \left( \frac{2F}{mD^2} - P_t \right) \quad (4)$$

(d) The design repair laminate thickness, $t_{repair}$, shall be the greater value determined from eqs. (3) and (4).

(e) Where the purpose of the Repair System is to strengthen an undamaged section of the component to carry additional bending or other axial loads, the value of $F$ shall be taken to be the increased total axial load requirement and the value of $P_t$ shall be the original MAWP/MAOP. The value of $F$ depends on the specific application details and shall be considered by the Repair System designer (outside the scope of this Article).

### 3.4.3.2 Underlying Substrate Yields

(a) In the derivation of eqs. (5) and (6) it is assumed that the underlying substrate does yield and the repair laminate is designed based on the allowable strain of the composite. Only hoop loading should be considered in determining the design repair laminate thickness.

(b) For hoop strain due to internal pressure, the design repair laminate thickness, $t_{repair}$, may be calculated by iteration using

$$\varepsilon_t = \frac{PD}{2E_c} t_{repair} - s_t - \frac{P_{live}D}{2(E_c t_{repair} + E_s s_t)} \quad (5)$$

(c) If the repair is applied at zero internal pressure, i.e., $P_{live} = 0$, then eq. (5) can be rearranged to give

$$t_{repair} = \frac{1}{\varepsilon_t} \left( \frac{PD}{2} - st_t \right) \quad (6)$$

(d) The assumptions made in deriving eqs. (5) and (6) are that the substrate material is elastic, perfectly plastic, i.e., no strain hardening and that no defect assessment is performed other than use of the minimum remaining wall thickness (of the substrate) to infer the internal pressure at the point of substrate yield.

(e) The value of the allowable strain of the composite in the circumferential direction can be taken from eqs. (10a) and (10b) or if performance data are available, from Mandatory Appendix V. The appropriate service factor is taken from Table 4.

(f) For axial loads in pipelines, eq. (7) shall be utilized.

$$t_{repair} = \frac{1}{\varepsilon_{tE_c}} \left( \frac{PD}{4} - st_t \right) \quad (7)$$

where $t_t$ may be conservatively the minimum wall thickness or the equivalent remaining wall thickness based on the defect assessment.

### Table 3 Allowable (Long Term) Strains for Repair Laminates (No Allowance for Temperature Effects)

<table>
<thead>
<tr>
<th>Load Type</th>
<th>Symbol</th>
<th>Rarely Occurring, %</th>
<th>Continuous (Sustained), %</th>
</tr>
</thead>
<tbody>
<tr>
<td>For $E_c \geq 0.5 E_t$</td>
<td>$\varepsilon_{t0}$</td>
<td>0.40</td>
<td>0.25</td>
</tr>
<tr>
<td>For $E_c &lt; 0.5 E_t$</td>
<td>$\varepsilon_{t0}$</td>
<td>0.40</td>
<td>0.25</td>
</tr>
<tr>
<td>Circumferential</td>
<td>$\varepsilon_{t0}$</td>
<td>0.40</td>
<td>0.25</td>
</tr>
<tr>
<td>Axial</td>
<td>$\varepsilon_{t0}$</td>
<td>0.25</td>
<td>0.10</td>
</tr>
</tbody>
</table>

### 3.4.4 Repair Laminate Allowable Strains

(a) Use of the design method in this section is appropriate if the contribution of the original component is to be ignored in the calculation for load-carrying capability and if short-term material properties are to be used.

(b) The allowable repair laminate strain method is a function of design temperature.

(c) For hoop stresses due to internal pressure, the minimum repair laminate thickness, $t_{min}$, is given by

$$t_{min} = \frac{1}{\varepsilon_t} \left( \frac{PD}{2} - \frac{E_c}{E_p} u_{/e} \right) \quad (8)$$

(d) For axial stresses due to internal pressure, bending, and axial thrust, the minimum repair laminate thickness, $t_{min}$, is given by

$$t_{min} = \frac{1}{\varepsilon_t} \left( \frac{F}{\pi D E_c} - \frac{PD u_{/e}}{2 E_c} \right) \quad (9)$$

(e) The design repair laminate thickness, $t_{repair}$, shall be the greater value determined from eqs. (8) and (9).

(f) Rarely occurring events (e.g., pressure excursions above design pressure) may be assessed using the strains given in Table 3, provided that they occur typically less than ten times in the life of the component with each duration less than 30 min.

(g) The continuous (sustained) long-term allowable strains listed in Table 3 shall only be used if the short-term tensile strain to failure of the repair laminate is at least 1%, otherwise performance data derived according to para. 3.4.5 shall be used. The short-term strain to failure shall be derived from the test carried out to determine the tensile properties of the laminate (Table 1).

(h) Some Repair System suppliers may choose to use laminate analysis to calculate modulus values for laminates built up from a series of different layers. This is satisfactory, provided that the results from the laminate analysis have been validated using measured data.

(i) Thermal expansion coefficients for composite Repair Systems are different than those for the substrate, so thermal stresses will be generated where operating temperatures vary from installation temperature. Where this absolute temperature change is greater than 40°C (72°F), the effect of differential thermal expansion between the repair laminate and the substrate shall be considered in the design assessment.
### 3.4.4 Repair Laminate Allowable Strains

(a) Use of the design method in this section is appropriate if the contribution of the original component is to be ignored in the calculation for load-carrying capability and if short-term material properties are to be used.

(b) The allowable repair laminate strain design method is a function of design temperature.

(c) For hoop stresses due to internal pressure, the minimum repair laminate thickness, \( t_{\text{min}} \), is given by

\[
t_{\text{min}} = \frac{1}{\varepsilon_c} \left( \frac{2PD}{E_c} - \frac{F}{\pi D E_c} \right)\]  

(d) For axial stresses due to internal pressure, bending, and axial thrust, the minimum repair laminate thickness, \( t_{\text{min}} \), is given by

\[
t_{\text{min}} = \frac{1}{\varepsilon_a} \left( \frac{F}{\pi D E_a} - \frac{PD \nu_{\text{a}}}{2} - \frac{E_a}{E_c} \right)\]  

(e) The design repair laminate thickness, \( t_{\text{design}} \), shall be the greater value determined from eqs. (8) and (9).

(f) Rarely occurring events (e.g., pressure excursions above design pressure) may be assessed using the strains listed in Table 3, provided that they occur typically less than ten times in the life of the component with each duration less than 30 min.

(g) The continuous (sustained) long-term allowable strains listed in Table 3 shall only be used if the short-term tensile strain to failure of the repair laminate is at least 1%, otherwise performance data derived according to para. 3.4.5 shall be used.

(h) The short-term strain to failure shall be derived from the test carried out to determine the tensile properties of the laminate (Table 1).

(i) Some Repair System suppliers may choose to use laminate analysis to calculate modulus values for laminates built up from a series of different layers. This is satisfactory, provided that the results from the laminate analysis have been validated using measured data.

(j) Thermal expansion coefficients for composite Repair Systems are different than those for the substrate, so thermal stresses will be generated where operating temperatures vary from installation temperature. Where this absolute temperature change is greater than 40°C (72°F), the effect of differential thermal expansion between the repair laminate and the substrate shall be considered in the design assessment.

(k) The allowable repair laminate strains (circumferential and axial) shall be calculated by

\[
\varepsilon_c = f_{\text{t}} \varepsilon_{c0} - \Delta T (\alpha_c - \alpha_s) \]  

and

\[
\varepsilon_a = f_{\text{t}} \varepsilon_{a0} - \Delta T (\alpha_a - \alpha_s) \]  

where \( \varepsilon_{c0} \) and \( \varepsilon_{a0} \) are from Table 3.

### 3.4.5 Repair Laminate Allowable Stresses Determined by Performance Testing

(a) Use of the design method in this section is appropriate if performance-based test data are available.

(b) If allowance for the component is not to be included, then eq. (11) shall be used.

(c) For hoop stresses due to internal pressure, the minimum repair laminate thickness, \( t_{\text{min}} \), is given by

\[
t_{\text{min}} = \frac{PD}{2} \cdot \left( \frac{1}{f_{\text{t}} \cdot f_{\text{r}}} \right)\]  

(d) For axial stresses due to internal pressure, bending, and axial thrust, the minimum repair laminate thickness, \( t_{\text{min}} \), is given by eq. (4) or (9), as appropriate.

(e) The design repair laminate thickness, \( t_{\text{design}} \), shall be the greater of the values determined by paras. (c) and (d).

(f) If allowance for the component is to be included, then eq. (12) shall be used.

(g) For hoop stresses due to internal pressure, the design repair laminate thickness, \( t_{\text{design}} \), is given by

\[
t_{\text{design}} = \left( \frac{PD}{2} - t_d \right) \cdot \left( \frac{1}{f_{\text{t}} \cdot f_{\text{r}}} \right)\]  

(h) The service factor, \( f_{\text{s}} \), is the lesser of that obtained from Table 4 and from the appropriate construction code.

(i) The 1,000 hr data service factor shall be used if the product is qualified to the testing in Mandatory Appendix V, para. V-2.1. The design life data service factor may be used if the product is qualified to either para. V-2.2 or para. V-2.3.

### 3.4.6 Leaking Components

(a) Use of the design method in this paragraph is appropriate if the component is leaking or considered to be leaking at the end of its service life. The requirements of this paragraph are in addition to those described in para. 3.4.4 or 3.4.5.

(b) A (substrate) component shall be considered to be leaking if the wall thickness at any point of the affected...