### Table 4—Summary of Minimum Requirements—Continued

<table>
<thead>
<tr>
<th>Cargo name ¹</th>
<th>Ship type</th>
<th>Independent tank type C required</th>
<th>Control of cargo tank vapor space</th>
<th>Vapor detection²</th>
<th>Gauging³</th>
<th>Electrical hazard class and group⁴</th>
<th>Special requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene oxide</td>
<td>IG</td>
<td>Yes</td>
<td>Inert</td>
<td>I &amp; T</td>
<td>C</td>
<td>I-B</td>
<td>154.660 (b) (3), 154.1400 (c), 154.1405, 154.1410, 154.1702 (b), (d), (f), 154.1705, 154.1710, 154.1720, 154.1725, 154.1730, 154.1870 (a), (b).</td>
</tr>
<tr>
<td>Methane (LNG)</td>
<td>IIG</td>
<td></td>
<td></td>
<td>I</td>
<td>C</td>
<td>I-D</td>
<td>154.703 through 154.709, 154.1854.</td>
</tr>
<tr>
<td>Methyl acetylene-propylene mixture.</td>
<td>IIG/IIPG</td>
<td></td>
<td></td>
<td>I</td>
<td>R</td>
<td>I</td>
<td>154.1735.</td>
</tr>
<tr>
<td>Methyl bromide.</td>
<td>IG</td>
<td>Yes</td>
<td>Inert</td>
<td>I &amp; T</td>
<td>C</td>
<td>I-D</td>
<td>154.660 (b) (3), 154.1400 (c), 154.1405, 154.1410, 154.1702 (a), (d), 154.1705, 154.1720, 154.1870 (a), (b).</td>
</tr>
<tr>
<td>Methyl chloride.</td>
<td>IIG/IIPG</td>
<td></td>
<td></td>
<td>I &amp; T</td>
<td>C</td>
<td>I-D</td>
<td>154.1702 (a), 154.1870.</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>IIG</td>
<td></td>
<td></td>
<td>O</td>
<td>C</td>
<td>I-D</td>
<td>154.1755.</td>
</tr>
<tr>
<td>Propane</td>
<td>IIG/IIPG</td>
<td></td>
<td></td>
<td>I</td>
<td>R</td>
<td>I-D</td>
<td>None.</td>
</tr>
<tr>
<td>Propylene</td>
<td>IIG/IIPG</td>
<td></td>
<td></td>
<td>I</td>
<td>R</td>
<td>I-D</td>
<td>None.</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>IIG</td>
<td></td>
<td></td>
<td>Dry</td>
<td>T</td>
<td>C</td>
<td>None.</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>IG</td>
<td>Yes</td>
<td>Dry</td>
<td>T</td>
<td>C</td>
<td>I-D</td>
<td>154.1405, 154.1410, 154.1702 (a), (b) (d), (f), 154.1710, 154.1740, 154.1745, 154.1750, 154.1818, 154.1830 (f), 154.1870.</td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>IIG/IIPG</td>
<td></td>
<td></td>
<td>I &amp; T</td>
<td>C</td>
<td>I-D</td>
<td>None.</td>
</tr>
</tbody>
</table>

¹ Refrigerant gases include non-toxic, non-flammable gases such as: dichlorodifluoromethane, dichloromonofluoromethane, dichlorotetrafluoroethane, monochlorodifluoromethane, monochlorotetrafluoroethane, and monochlorotrifluoromethane.

² As used in this column: “I” stands for flammable vapor detection; “T” stands for toxic vapor detection; “O” stands for oxygen detection; and see §§ 154.1345 thru 154.1360.

³ As used in this column: “C” stands for closed gauging; “R” stands for restricted gauging; and see § 154.1300.

⁴ The designations used in this column are from the National Electrical Code.


### APPENDIX A TO PART 154—EQUIVALENT STRESS

I. Equivalent stress \( (\sigma_c) \) is calculated by the following formula or another formula

\[
\sigma_c = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau_{xy}^2}
\]

where:

- \( \sigma_x \) = total normal stress in “x” direction.
- \( \sigma_y \) = total normal stress in “y” direction.
- \( \tau_{xy} \) = total shear stress in “xy” plane.

specially approved by the Commandant (CG–522) as equivalent to the following:
II. When the static and dynamic stresses are calculated separately, the total stresses in paragraph I are calculated from the following formulae or another formulae specially approved by the Commandant (CG–522) as equivalent to the following:

\[ \sigma_x = \sigma_x^{(\text{static})} \pm \sqrt{\sum (\sigma_x^{(\text{dynamic})})^2} \]

\[ \sigma_y = \sigma_y^{(\text{static})} \pm \sqrt{\sum (\sigma_y^{(\text{dynamic})})^2} \]

\[ \tau_{xy} = \tau_{xy}^{(\text{static})} \pm \sqrt{\sum (\tau_{xy}^{(\text{dynamic})})^2} \]

III. Each dynamic and static stress is determined from its acceleration component and its hull strain component from hull deflection and torsion.


APPENDIX B TO PART 154—STRESS ANALYSES DEFINITIONS

The following are the standard definitions of stresses for the analysis of an independent tank type B:

**Normal stress** means the component of stress normal to the plane of reference.

**Membrane stress** means the component of normal stress that is uniformly distributed and equal to the average value of the stress across the thickness of the section under consideration.

**Bending stress** means the variable stress across the thickness of the section under consideration, after the subtraction of the membrane stress.

**Shear stress** means the component of the stress acting in the plane of reference.

**Primary stress** means the stress produced by the imposed loading that is necessary to balance the external forces and moments. (The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses that considerably exceed the yield strength result in failure or at least in gross deformations.)

**Primary general membrane stress** means the primary membrane stress that is so distributed in the structure that no redistribution of load occurs as a result of yielding.

**Primary local membrane stress** means the resulting stress from both a membrane stress, caused by pressure or other mechanical loading, and a primary or a discontinuity effect that produces excessive distortion in the transfer of loads to other portions of the structure. (The resulting stress is a primary local membrane stress although it has some characteristics of a secondary stress.)

A stress region is local if:

\[ S_1 \leq 0.5 \sqrt{\frac{R}{t}} \]; and

\[ S_2 \leq 2.5 \sqrt{\frac{R}{t}} \]

where:

\[ S_1 = \text{distance in the meridional direction over which the equivalent stress exceeds 1.1 f.} \]

\[ S_2 = \text{distance in the meridional direction to another region where the limits for primary general membrane stress are exceeded.} \]

\[ R = \text{mean radius of the vessel.} \]

\[ t = \text{wall thickness of the vessel at the location where the primary general membrane stress limit is exceeded.} \]

\[ f = \text{allowable primary general membrane stress.} \]

**Secondary stress** means a normal stress or shear stress caused by constraints of adjacent parts or by self-constraint of a structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions that cause the stress to occur.

PART 155 [RESERVED]