# Article 5.1, Mandatory Appendix II
# Stored Energy Calculations for Pneumatic Pressure Test

The stored energy of the equipment or piping system should be calculated and converted to equivalent kilograms (pounds) of TNT (Trinitrotoluene) using the following equations:

$$E = \left[1/(k-1)\right] \times P_{at} \times V \left[1 - (P_a/P_{at})^{[(k-1)/k]}\right] \quad \text{(II-1)}$$

where
$E$ = stored energy, J (ft-lb)
$k$ = ratio of specific heat for the test fluid
$P_a$ = absolute atmospheric pressure, 101 kPa (14.7 psia)
$P_{at}$ = absolute test pressure, Pa (psia)
$V$ = total volume under test pressure, $m^3$ ($ft^3$)

When using air or nitrogen as the test medium ($k = 1.4$), this equation becomes

$$E = 2.5 \times P_{at} \times V \left[1 - (P_a/P_{at})^{0.286}\right] \quad \text{(II-2)}$$

and

$$\text{TNT} = \frac{E}{4266920} \text{ (kg)} \quad \text{(II-3)}$$

where
$E$ = stored energy, J
$P_a$ = absolute atmospheric pressure, 101 000 Pa
$P_{at}$ = absolute test pressure, Pa
$V$ = total volume under test pressure, $m^3$

For U.S. Customary units using air or nitrogen as the test medium ($k = 1.4$), this equation becomes

$$E = 360 \times P_{at} \times V \left[1 - (P_a/P_{at})^{0.286}\right] \quad \text{(II-4)}$$

and

$$\text{TNT} = \frac{E}{1488617} \text{ (lb)} \quad \text{(II-5)}$$

where
$E$ = stored energy, ft-lb
$P_a$ = absolute atmospheric pressure, 14.7 psia
$P_{at}$ = absolute test pressure, psia
$V$ = total volume under test pressure, $ft^3$

See also paras. 6.2(e) and 6.2(f) of Article 5.1.

# Article 5.1, Mandatory Appendix III
# Safe Distance Calculations for Pneumatic Pressure Test

The minimum distance between all personnel and the equipment being tested shall be the greater of

*(a)* the following:

*(1)* $R = 30$ m for $E \leq 135\,500\,000$ J

*(2)* $R = 60$ m for $135\,500\,000$ J $< E \leq 271\,000\,000$ J

*(3)* $R = 100$ ft for $E < 100{,}000{,}000$ ft-lb

*(4)* $R = 200$ ft for $100{,}000{,}000 < E \leq 200{,}000{,}000$ ft-lb

*(b)* the following equation:

$$R = R_{\text{scaled}}\,(\text{TNT})^{1/3} \tag{III-1}$$

where

$E$ = stored energy as calculated by eq. (II-1) or (II-2)

$R$ = actual distance from equipment

$R_{\text{SCALED}}$ = scaled consequence factor; value for eq. (III-1) shall be 20 m/kg$^{1/3}$ (50 ft/lb$^{1/3}$) or greater

TNT = energy measured in TNT, kg (lb), determined from eq. (II-3) or (II-5)

**Table III-1**

| $R_{\text{SCALED}}$, m/kg$^{1/3}$ | $R_{\text{SCALED}}$, ft/lb$^{1/3}$ | Biological Effect | Structural Failure |
|---|---|---|---|
| 20 | 50 | . . . | Glass windows |
| 12 | 30 | Eardrum rupture | Concrete block panels |
| 6 | 15 | Lung damage | Brick walls |
| 2 | 5 | Fatal | . . . |

For systems where $E > 271\,000\,000$ J (200,000,000 ft-lb), the required distance shall be calculated by eq. (III-1).

If the minimum calculated distance cannot be obtained, an alternative value for $R_{\text{SCALED}}$ may be chosen based on Table III-1 for use in eq. (III-1). See also para. 6.2(g).

For example, to prevent lung damage, the distance a person is from the equipment should result in an $R_{\text{SCALED}}$ value of more than 6 m/kg$^{1/3}$ (15 ft/lb$^{1/3}$). Note the structural damage that can occur, which shall be considered.

# Article 5.1, Mandatory Appendix IV
# Risk Evaluation Considerations for Pneumatic Pressure Test

When considering the risk analysis factors listed in para. 6.2(f), it should be remembered that risk is a two-dimensional combination of probability (or likelihood) and consequence. Risk is the measure of the potential for harm or loss (i.e., hazard) that reflects the likelihood (or frequency) and severity of an adverse effect to health, property, or the environment. If probability and consequence are defined quantitatively (i.e., numerical values are assigned), risk is the product.

$$\text{Risk} = \text{Probability} \times \text{Consequence} \qquad \text{(IV-1)}$$

In a qualitative assessment, a matrix is typically used to combine probability and consequence. Consideration should be given to the level of risk that is acceptable when performing pneumatic tests. Reference API RP 580 for use of risk assessment in determining the acceptable levels of risk associated with pneumatic testing.

In reviewing eq. (IV-1), it is clear that even though the consequence may be significant, if the probability is very low, the risk may become acceptable. For example, the consequence of an airliner crashing is significant in that it will most likely result in serious injury or death to the passengers along with major damage or total loss of the aircraft. However, the probability of the airliner crashing is very low; thus, the public accepts the risk associated with airline travel.

Risk considerations can be applied to pneumatic testing also. Examples may include

*(a)* a new austenitic stainless steel piping system that has been hydrostatically tested during shop fabrication with the exception of four final field assembly circumferential butt welds. The piping system has a total volume that results in an energy level greater than 271 000 000 J (200,000,000 ft-lb); however, it is not feasible to separate the piping system into smaller sections for testing, nor is it feasible to install blast barriers. By performing volumetric examination such as UT or RT and determining the field welds are free of rejectable indications, the risk associated with a full pneumatic pressure test of this system may be deemed acceptable.

*(b)* an existing carbon steel vessel with an MDMT rating of −45°C (−50°F) into which a new nozzle had been installed following all requirements of the original Code of Construction. The vessel has a total volume that results in an energy level greater than 271 000 000 J (200,000,000 ft-lb); however, it is still desired to perform a pressure test to check the integrity of the weld and obtain the other benefits of pressure testing. It is not feasible to install blast barriers. By performing volumetric examination such as UT on the nozzle attachment weld and determining the weld is free of rejectable indications, along with verification by inspection that the vessel is in a like-new condition, the risk associated with a full pneumatic pressure test of this vessel may be deemed acceptable.