

# Task Force on Tank Pressure Coordination

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3:15 PM – 4:30 PM

Hilton Toronto

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## Agenda:

1. Introductions
2. Patent Disclosure Request
3. Approval of the Minutes of Meeting of March 2010 in Houston, TX.
4. Report on Progress of Task Force
  - Summary of Agreements from last meeting
  - Proposal of Standardized Text for Tank Withstand and PRV Requirements
  - Document history behind tank strength and PRV requirements for future reference
5. Next Meeting
6. Adjournment

## Summary of Agreements from last meeting

- Potential Transformer Failure Modes discussed:
  - Static Pressure
  - Dynamic Pressure
- Dynamic Pressure requirements exclusive of overhead transformers
  - Padmounted transformers several times stronger due to rectangular shape
- Work of Task Force to focus on Coordination of Static Pressure Requirements
  - Tank Strength
  - PRV Requirements

# Current Requirements on Distribution Transformers Standards

Standard	Static Pressure	Pressure relief device
<p>Overhead type C57.12.20-2005</p>	<p>7.2.5.2 Cover assembly A cover assembly designed to relieve excess pressure in the transformer tank shall remain effectively sealed for overloads and external secondary short circuits of the magnitude and duration allowed by industry standards and loading guides. The assembly shall relieve pressure at a minimum of 56 kPa (gage) <b>(8 psig)</b> if designed to reseal, or at a minimum of 138 kPa (gage) <b>(20 psig)</b> if designed for pressure relief without resealing. Such operation shall occur before other components of the tank are ruptured or displaced, and the cover shall remain in position. Manual means of venting the tank before removal of the cover shall be provided. The flow rate shall be at least equal to that of the pressure-relief device specified in 7.2.5.1.</p> <p>7.2.6.1 Static pressure The completely assembled transformer enclosure shall be of sufficient strength to withstand an internal pressure of <b>49 kPa (gage) (7 psig)</b> without permanent distortion to the enclosure. The enclosure shall also be of sufficient strength to withstand an internal pressure of 138 kPa (gage) <b>(20 psig)</b> without rupturing or displacing components (excluding the cover gasket and gasket oil leaks) of the transformer</p>	<ul style="list-style-type: none"> <li>- Venting pressure = 69 kPa <b>(10 psig)</b> ± 13 kPa (gage) (2 psig)</li> <li>- Resealing pressure = 42 kPa (gage) (6 psig) minimum</li> <li>- Zero leakage from reseal pressure to -56 kPa (gage) (8 psig)</li> <li>- Flow at 103 kPa (gage) (15 psig) = 16.5 L/s (35 Standard Cubic Feet per Minute {SCFM}) minimum, corrected for air pressure of 101 kPa (14.7 psi) (absolute) and air temperature of 21 °C.</li> </ul>
<p>Single phase Padmounted Type C57.12.38-2009</p>	<p>10.2 Strength The tank shall be of sufficient strength to withstand a gage pressure of 50 kPa <b>(7 psig)</b> without permanent distortion and 103 kPa <b>(15 psig)</b> without rupturing or affecting cabinet security as described in IEEE Std C57.12.28.</p>	<p>Venting pressure = 69 kPa ± 13 kPa <b>(10 psig ± 2 psig)</b>                      Resealing pressure = 42 kPa (6 psig) minimum                      Zero leakage from resealing pressure to -56 kPa (-8 psig)                      Flow at 103 kPa (15 psig) = 16.5 L/s (35 SCFM) minimum of air at a standard temperature and pressure. Standard temperature is 21 °C and standard pressure is 101 kPa (14.7 psig).</p>
<p>Three phase Padmounted Type C57.12.34-2009</p>	<p>8.10 Tanks 8.10.1 Strength The tank shall be of sufficient strength to withstand a gage pressure of 50 kPa <b>(7 psig)</b> without permanent distortion, as well as a gage pressure of 103 kPa <b>(15 psig)</b> without rupturing or affecting cabinet security as described in IEEE Std C57.12.28.</p>	<p>Cracking pressure: 69 kPa(gage) ±13 kPa(gage) <b>(10 psig ± 2 psig)</b>                      Resealing pressure: 42 kPa(gage) (6 psig) minimum                      Zero leakage from resealing pressure to -56 kPa(gage) (-8 psig)                      Flow at 103 kPa (gage): 16.5 L/s minimum of air at a standard temperature and pressure. Standard temperature is 21°C and standard pressure is 101 kPa (absolute) (Flow at 15 psig: 35 SCFM minimum where SCFM is flow at cubic feet per minute, corrected for an air pressure of 14.7 psi and an air temperature of 21°C.)</p>

# Current Requirements on Distribution Transformers Standards

Standard	Static Pressure	Pressure relief device
<p>Three phase Submersible type C57.12.24- 2009</p>	<p>7.5.2 Tank integrity The transformer shall be of sealed-tank construction as defined in IEEE Std C57.12.80-2002. The transformer shall remain effectively sealed for a top oil temperature range of <math>-5\text{ }^{\circ}\text{C}</math> to <math>+120\text{ }^{\circ}\text{C}</math> under operating conditions as described in IEEE Std C57.91-1995. The completely assembled transformer tank shall be of sufficient strength to withstand a static internal pressure of 50 kPa gauge (<b>7 psig</b>) without permanent distortion and 103 kPa gauge (<b>15 psig</b>) without rupturing. The completely assembled transformer shall be tested for leaks at a minimum of 50 kPa gauge (<b>7 psig</b>) measured above the static head of liquid for not less than six hours. Alternative methods for leak detection such as helium leak detector method may be used.</p>	<p>7.3 Accessories A 1/2 in or larger NPT fitting sized for specified minimum flow rate shall be provided for the installation of a pressure-relief device.</p>
<p>Single phase Underground type C57.12.23- 2009</p>	<p>7.5 Transformer tank integrity The completely assembled transformer tank shall be of sufficient strength to withstand a static internal pressure of 50 kPa gauge (7 psig) without permanent distortion and 140 kPa gauge (20 psig) without rupturing.</p>	<p>7.3 Accessories .... A 1/2 in or larger National Pipe Thread (NPT) or National Coarse (NC) thread fitting with gasket shall be provided for pressure relief. The pressure relief fitting shall allow slow release of pressure without completely removing the fitting.</p>

## Standardized Text for Tank Withstand and PRV Requirements

### Standardization Opportunities:

1. Inconsistent pressure values in SI Units (kPa)
2. “Cracking pressure” or “Venting pressure” for PRV
3. Notation for Dual dimensioning with tolerance
4. kPa values with and without “gage” notation

# Standardized Text for Tank Withstand and PRV Requirements

## 1. Inconsistent pressure values in SI Units (kPa)

From: C57.144-2004 IEEE Guide for Metric Conversion of Transformer Standards

Annex A

A.3 Pressure relief valve

e) "Resealing pressure of 6 psig minimum," assuming accuracy of 10%, yields  $6 \times 6.894757 = 41.368$  and rounded up is 42 kPa (gauge) minimum

Using conversion factor to calculate rounded pressure values part of the standards:

Conversion Factor	psig	kPa (calculated)	kPa (proposed rounded)	kPa values on Dist. Standards
6.894757	6	41.37	42	42
6.894757	7	48.26	49	49; 50
6.894757	8	55.16	56	56
6.894757	10	68.95	69	69
6.894757	15	103.42	103	103
6.894757	20	137.90	138	138; 140

# Standardized Text for Tank Withstand and PRV Requirements

## 2. “Cracking pressure” or “Venting pressure” for PRV

- Technical literature of 5 PRV manufacturers was reviewed
  - 3 used term “cracking pressure”
  - 2 used term “operating pressure”
- Recommendation to use “Cracking pressure” as the standard term

# Standardized Text for Tank Withstand and PRV Requirements

## 3. Notation for Dual dimensioning with tolerance

- Some Standards with Separate notations of U.S. Customary and their SI Units conversion for specified values and their tolerances
  - Example: 69 kPa (10 psig)  $\pm$  13 kPa (gage) (2 psig)
- Other Standards with grouped notations of U.S. Customary and their SI Units conversion
  - Example: 69 kPa  $\pm$  13 kPa (10 psig  $\pm$  2 psig)
- From: C57.144-2004 IEEE Guide for Metric Conversion of Transformer Standards:

### 3.19 Dual dimensioning

When dual dimensioning, group each value and its tolerance together. It may be easier to understand when each unit is given only once.

Examples:

50.80  $\pm$  0.02 mm (2.000  $\pm$  0.001 in)

or

1380 kPa  $\pm$  100 kPa (200 psi  $\pm$  15 psi)

- Therefore, the proposed notation is: 69 kPa(gage)  $\pm$ 13 kPa(gage) (10 psig  $\pm$  2 psig)

# Standardized Text for Tank Withstand and PRV Requirements

## 4. kPa values with and without “gage” notation

- Several styles on how to handle kPa values with or without gage notation were found:
  - 69 kPa (10 psig) ± 13 kPa (gage) (2 psig)
  - 69 kPa ± 13 kPa (10 psig ± 2 psig)
  - 69 kPa(gage) ±13 kPa(gage) (10 psig ± 2 psig)

- From: C57.144-2004 IEEE Guide for Metric Conversion of Transformer Standards:

### 3.9 Gauge and absolute pressure

Gauge (or gage) and absolute pressures must be stated as such or be obvious from the context. There is no metric equivalent to “psia” or “psig”.

- Therefore, the proposed notation is: 69 kPa(gage) ±13 kPa(gage) (10 psig ± 2 psig)

## Standardized Text for Tank Withstand and PRV Requirements

- Proposed Standardized Text for PRV Requirements:
- (same as C57.12.34-2009)


Cracking pressure: 69 kPa(gage)  $\pm$ 13 kPa(gage) (10 psig  $\pm$  2 psig)

Resealing pressure: 42 kPa(gage) (6 psig) minimum

Zero leakage from resealing pressure to  $-56$  kPa(gage) ( $-8$  psig)

Flow at 103 kPa (gage): 16.5 L/s minimum of air at a standard temperature and pressure. Standard temperature is 21°C and standard pressure is 101 kPa (absolute) (Flow at 15 psig: 35 SCFM minimum where SCFM is flow at cubic feet per minute, corrected for an air pressure of 14.7 psi and an air temperature of 21°C.)

## History of tank strength and PRV requirements

- PRVs have been used to protect transformer tanks for more than 30 years
- Main factors involved on transformer internal pressure: [1] [2]
  - Oil expansion due to heating
  - Pressure temperature effects on the gas
  - Tank wall deflection
  - Solubility of the gas in transformer oil
- As the oil expands and compresses the gas space, more gas would dissolve in oil
  - Equilibrium may take days or even weeks for non-agitated oil
  - On transformer cool down cycles, negative (vacuum) pressures can be developed due to equilibrium long time constant
- Accurate internal pressure levels can be calculated if initial condition of pressure, temperature and ratio of gas to oil is known
- Internal pressures calculated considering solubility are substantially lower than when using the Gas Law 
  - Internal tank pressure calculation of less than 7 psig for normal loading conditions
- Internal Pressure levels of 10 psig reached either on severe (unsafe) overloading, or on high impedance internal faults [3] [4]

## History of tank strength and PRV requirements

### Conclusions from the investigation:

- PRV is meant to prevent unsafe condition of transformer static pressure due to:
  - Severe sustained overloading
  - High impedance internal faults with long period of arcing time
- PRV is not meant to prevent a permanent tank distortion condition
  - Calculated pressures for normal transformer operation well below 7 psig
- Therefore, present requirements of: tank strength of 7psi without permanent distortion and PRV cracking pressure of 10 psig are considered to be adequate

## Next Meeting

- Spring 2011. April 10-14. San Diego
- Pending Tasks to be completed by next meeting:
  - Obtain Feedback from Task Force Members
  - Send to WG of distribution transformer product standards:
    - Proposed editorial changes to Tank Strength and PRV Requirements
    - Documentation of the TF Investigation to be considered as informative annex on future revisions of the standards

# Bibliography

[1] E.W. Tipton, "Variations of Tank Pressure with Transformer Loading in Sealed Transformers"; AIEE Transactions, 1950

[2] T.V. Oommen, "Gas Pressure Calculations for Sealed Transformers Under Varying Load Conditions"; IEEE Transactions on Power Apparatus and Systems, 1983

[3] E.A. Goodman, L. Zupon, "Static Pressures Developed in Distribution Transformers due to internal arcing under oil"; IEEE Transactions on Power Apparatus and Systems, 1976

[4] J.M. Lunsford, T.J. Tobin, "Detection of and Protection for Internal Low-Current Winding Faults in Overhead Distribution Transformers", IEEE Transactions on Power Delivery, 1977.

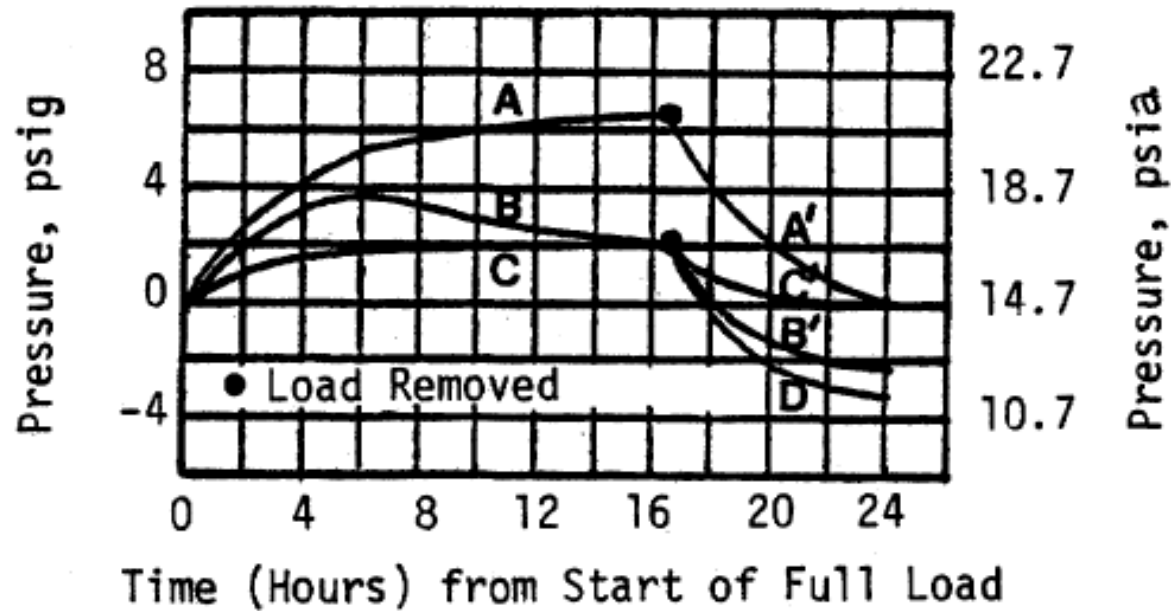


Figure 4. Pressure-Load Time Curves

- AA': Computed, ignoring solubility
- BB': Measured in Tipton's Study
- CC': Equilibrium curve
- D : Computed, ignoring solubility,  
with end of load as starting point

Maximum pressure may develop at an early stage of the load cycle due to slow dissolution of gas in oil

