

# Task Force on Tank Pressure Coordination

## Objective

- Review and resolve any potential conflicts caused by the current requirements for the mechanical strength of the enclosure and the pressure relief valve
- Define a standardized wording to be adapted and incorporated into the different distribution transformer product standards

# Description of Current Situation

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 49 kPa (gage) <b>(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 C57.12.34-2004</p>	<p>9.10 Tanks 9.10.1 Strength The tank shall be of sufficient strength to withstand a gage pressure of 50 kPa <b>(7 psig)</b> without permanent distortion; and 103 kPa <b>(15 psig)</b> without rupturing or affecting cabinet security as described in ANSI 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>

# Description of Current Situation

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- 2002</p>	<p>6.5 Tanks The tank shall be of sufficient strength to withstand a static internal pressure of 50 kPa gauge without permanent distortion and 140 kPa gauge without rupturing.[5] [5] 50 kPa = <b>7 lbf/in<sup>2</sup></b>; 140 kPa = <b>20 lbf/in<sup>2</sup></b></p>	<p>6.5 Tanks .... A 1/2 inch or larger NPT fitting sized for specified minimum flow rate shall be provided for the installation of a pressure-relief device.</p>

# Description of Current Situation

Standard	Dynamic Pressure
<p>Overhead type C57.12.20- 2005</p>	<p>7.2.6.2 Dynamic pressure The completely assembled transformer enclosure shall be capable of passing the fault current tests as defined in Clause 9</p> <p>9.3 Tests Two tests are covered in this standard. Test Number 1 with a high-current arcing fault, without internal fusible elements, shall be conducted on each enclosure diameter with its minimum designed air space. The minimum designed air space must consider production tolerances. See 9.4. In addition, Test Number 2, with an internal fusible element, shall be conducted on each enclosure diameter utilizing the internal fusible elements. This test covers the interruption of these fusible elements for both rated interrupting and the lower fault value of current, as identified in 9.5. It is the intent of this test to utilize the highest energy release fuse element for each enclosure. This is probably the highest interrupting rated fuse element provided for the highest voltage class. The transformer shall not have a secondary breaker, or any other secondary protection.</p> <p>9.6 Test results No mechanical components from the transformer enclosure shall be propelled or dropped from the tank during the tests. There shall be no rupture of the tank casing or seams. There shall be less than 1 L (1 qt) of oil emitted and no expulsion of flaming oil during the tests. No oil shall continue to leave the inside of the transformer enclosure after the completion of the fault. The transformer shall not be dislodged from its Mounting.</p>
<p>Single phase Padmounted Type C57.12.38- 2009</p>	<p>There is no reference to fault current capability requirements</p>
<p>Three phase Padmounted Type C57.12.34- 2004</p>	<p>There is no reference to fault current capability requirements</p>
<p>Three phase Submersible type C57.12.24- 2009</p>	<p>7.5.2 Tank integrity .... The completely assembled transformer tank shall be capable of passing the fault current tests as defined in IEEE Std C57.12.20-2005.</p>
<p>Single phase Underground type C57.12.23- 2002</p>	<p>6.5 Tanks .... The completely assembled transformer enclosure shall be capable of passing the fault current tests as defined in ANSI C57.12.20-1997.</p>

# Description of Current Situation

## Definitions of Potential Transformer Failure Modes:

- Static Pressure.-
  - Slow rising pressure, either caused by a sustained overload, or by a progressive high impedance fault (between turns or between layers) [1]
  - A venting cover or a pressure relief valve can prevent an eventful failure in this condition. PRVs are mechanical-valve type devices with a response time of the order of 0.016 s (1 cycle). They are therefore ineffective in reducing maximum pressures if the total pressure rise occurs in 0.016 s or less [2]
- Dynamic Pressure.-
  - Sudden pressure rise, caused by a low impedance, short time, high energy internal fault [3]
  - Can cause an eventful failure, and it's the most difficult failure mode to contain from the standpoint of cover retention and tank rupture [3]
  - Typically last 1 cycle, and is relieved by the operation of an expulsion fuse [4]

## Identified issues

- Inconsistencies in references to pressure levels in both Imperial (US), and International System of Units (Metric)
- Apparent conflict between withstand requirement of 50 kPa (7 psig) for the enclosures without permanent distortion, and pressure relief valve requirements of 69 kPa  $\pm$  13 kPa (10 psig  $\pm$  2 psig)
  - Lack of definition of “permanent distortion”
  - Mechanical design criteria accounts for a safety factor of 20% to 40% on stress calculations
  - Canada users have a practice of using a 5 +/- 2 psig for years without a problem. Would there be more PRV operations at these low venting pressure levels?, and if so, how many operations would the PRV stand without failure?
- No consideration of Dynamic Pressure requirements on standard documents for single and three phase padmount transformers. “Because of its size, shape, and construction, the padmounted tank is capable of absorbing many times more energy than a pole tank.” [5]
- Tank rupture levels currently either 20 psig (polemounts), or 15 psig (all others)
  - Is this rupture level related with a high energy internal fault?

## Potential Changes and items for discussion

- Propose standardized wording of pressure level on both Imperial and International Systems
- Determine if the present requirement of 69 kPa  $\pm$  13 kPa (10 psig  $\pm$  2 psig) is well coordinated with the tank withstand pressure of 50 kPa (7 psig) without permanent distortion
  - Definition of permanent distortion (define a test or verification procedure?)
  - Is there a real issue with transformers with distorted tanks in service because of a higher pressure setting of the PRV?; are there any reported cases or statistical data available?; how much distortion would those transformers show, and would that have any detrimental effects on the transformer operation?
- Add Dynamic Pressure requirements to padmounted transformer standards (C57.12.34 and C57.12.38)

# Bibliography

- [1] R.E. Benton, "Progress in Improving the Fault Current Capability of Overhead Transformer Enclosures"; IEEE/PES Transmission and Distribution Conference and Exposition, 1979
- [2] P.Barkan, L. Suppon, "Static Pressures Developed in Distribution Transformers due to internal arcing under oil"; IEEE Transactions on Power Apparatus and Systems, 1976
- [3] P. Barkan, B.L. Damsky, L.F. Ettliger, E.J. Kotski, "Overpressure Phenomena in Distribution Transformers with Low Impedance Faults: Experiment and Theory", 1976.
- [4] J.B. Dastous, M. Foata and A. Hammel, "Estimating Overpressures in Pole-Type Distribution Transformers Part 1: Tank Withstand Evaluation", IEEE Trans. Power Delivery, January 2003.
- [5] R.E. Benton, "Energy Absorption Capabilities of Pad Mounted Distribution Transformers with Internal Faults"; IEEE/PES Transmission and Distribution Conference and Exposition, 1979