Comparison of Standards – ANSI / IEEE and IEC

Prepared by the Task Force under the Standards Subcommittee
IEEE Transformers Committee

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The comparisons below are based on the latest published standards unless identified otherwise. It is the directive of the Standards Subcommittee to publish this comparison study each time a major standard (IEEE C57.12.00, C57.12.90, or IEC 60076-1) is approved and published. The purpose of this study is to provide list of major differences between IEEE and IEC standards to the members of the group working on these documents. In addition to these major documents, we will include comparisons of other standards and guides commonly used for Power Transformers. It is hoped that the readers would consider harmonizing the standards as best as they can as they develop these standards for the industry.

Comparison of Standards – ANSI / IEEE and IEC
C57.12.00-2010 with IEC 600076-1 (2000)
Vinay Mehrotra / Waukesha Electric Systems

Subject Issue	ANSI / IEEE		IEC	
	Standards	Requirements	Standard	Requirements
	C57.12.00-2010		IEC 60076-1	
Scope	1.1	Single and polyphase transformers with voltage of 601V or higher in the highest voltage winding are governed by the standard.	1.1	Single phase transformers with rated power less than 1 KVA and three phase power transformers less than 5 KVA are not governed by this standard.
Scope	1.1	The standard does not apply to the following Instrument transformers, step voltage and induction voltage regulators, arc transformers, rectifier transformers, specialty transformers, grounding transformers, mobile transformers and mine transformers	1.1	The standard does not apply to following Transformers with no winding with rated voltage higher than 1000V, instrument transformers, traction transformers mounted on rolling stock, starting transformers, testing transformers and welding transformers, explosion-proof and mining transformers, transformer for deep water applications. When IEC standards are not available for such categories of transformers, this part of IEC 60076 may still be applicable.
Word usage	1.2	Paragraph on usage of words shall, must, should and may in the specification.	-	-
Definitions	3	Reference to C57.12.80	3	Definitions included in standard

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Subject Issue	ANSI / IEEE		IEC	
	Standards	Requirements	Standard	Requirements
	C57.12.00-2010		IEC 60076-1	
Cooling air temperature limit	4.1.2.1 4.1.2.3	For air cooled ambient air temperature shall not exceed 40°C, and average temperature of air for any 24 hr period not to exceed 30°C. For water cooled ambient temperature of cooling water not exceed 30°C and average temperature for any 24 hr period not exceed 25°C. Minimum water temperature shall not be lower than 1°C, unless it includes antifreeze suitable for -20°C operation.	1.2.2 b)	Ambient air not below -25°C and not above +40°C. For water cooled water temperature at inlet not exceeding +25°C.
Liquid temperature limit	4.1.2.2	Not lower than -20°C when operating		Not addressed
Supply voltage	4.1.4	Harmonic content not addressed.	1.2.2 c)	The total harmonic content not exceeding 5% and an even harmonic content not exceeding 1%.
Load current	4.1.5	Harmonic factor not exceed 0.05 pu	1.2.2 d)	Harmonic content of load current not exceeding 5% of rated current.
Operation above rated voltage or below rated frequency	4.1.6, 4.1.6.1	Under full load secondary voltage and volts /Hz not exceed 105% of rated, at power factor >.8 & frequency at least 95% of rated.	4.4.3	Maximum over-fluxing (volts /Hz) within prescribed Um, of 5%. At K times rated current ($0 \leq K \leq 1$) the over-fluxing will be limited to $(U*fr/ Ur*f) * 100 \leq 110 -5K$
Installation environment	-	Not addressed	1.2.2 (f)	Pollution rate normal (IEC 60137 and IEC 60815), ground acceleration level is below 2 m/s2) Max ambient air temperature in an enclosure (acoustic enclosure) not supplied by manufacturer 40°C.

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Subject Issue	ANSI / IEEE		IEC	
	Standards	Requirements	Standard	Requirements
	C57.12.00-2010		IEC 60076-1	
Max continuous transformer operating voltage	4.1.6.2	Limits specified in C84.1	-	Not addressed
Step down operation	4.1.8	Unless specified designed for step down operation.	-	Not addressed
Unusual service conditions				
Insulation Level	4.3.2.1	Dielectric strength correction factors in Table1 for altitudes > than 1000m	1.2.1	External insulation at high altitude in IEC 60076-3 for oil immersed transformers and IEC 60076-11 for dry type transformers.
Scott-connected or T-connected transformers	5.3.2	Arrangements used to accomplish specified.	-	Not addressed
Rated KVA	5.4.1	The output that can be delivered at rated secondary voltage and rated frequency without exceeding specified temperature-rise	4.1.1(NOTE)	The apparent power input to the transformer. The power delivered by the secondary under rated loading differs from rated power.
Highest system voltage	5.5.1	Listed in Table 4	4.6	Reference to IEC 60076-3 for highest system voltage.
Transport	-	Not addressed	4.7.4	Transformer shall be designed to withstand a constant acceleration of 1g in all directions.
Categories for tapping voltage variations	-	Not addressed	5.2	Constant flux voltage variation, variable flux voltage variation & combined voltage variation described.
Rating of transformer taps	5.5.3	Transformers with LTC may have reduced capacity taps unless specified otherwise.	5.3	All taps shall be full power taps except when specified otherwise.
Specification of taps in enquiry and order	-	Not addressed	5.4	Necessary data required - which winding tapped , number of steps and tapping step, category of voltage variation and whether maximum current limitation applies.

Subject Issue	ANSI / IEEE		IEC	
	Standards	Requirements	Standard	Requirements
	C57.12.00-2010		IEC 60076-1	
Specification for short circuit impedance	-	Not addressed	5.5	For transformers with tapping range exceeding ± 5% from principal tapping, impedance values to be given at principal tapping and the extreme tapping exceeding 5%.
Load loss and temperature rise	-	Not addressed	5.6	For tapping range within ±5% or rated power not above 2500 KVA load loss guarantee and temperature rise refer to principal tapping. For tapping range > ±5% or rated power above 2500 KVA the losses shall be guaranteed at principal as well as any other tapping stated and " maximum current tapping" to be selected for temp. rise test.
Connections and phase displacement symbols	5.7.2	a) Connections are designated as delta , Y and zig zag. Reference to C57.12.70 for connection arrangements. b) The phasor diagram is oriented with phase 1 pointing halfway between 7 and 8 o'clock.	6	Connections indicated by Y, D or Z for high voltage and y, d or z for intermediate and low voltage. The winding connection letter for LV and intermediate winding is immediately followed by its phase displacement clock number. Open windings not connected together in the transformer are indicated as III (HV), or iii(intermediate or low voltage). Existence of stabilizing winding is indicated by a symbol +d after symbols of loadable windings. b) The high voltage winding phasor diagram is oriented with phase 1 pointing at 12 o'clock.

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Subject Issue	ANSI / IEEE		IEC	
	Standards	Requirements	Standard	Requirements
	C57.12.00-2010		IEC 60076-1	
Standard reference temperature	5.9	For load losses 85 °C and for no load losses 20°C	10.1 b)	Reference temperature 75°C for oil filled transformers.
Insulation levels	5.10	Dielectric insulation levels for Class I and Class II transformers included.	-	Not addressed.
Coordination of insulation levels	5.10.2.1 &5.10.2.2	BIL levels, BSL levels included.	-	Not addressed
Winding, oil, metallic and hot spot temperature rises	5.11.1.1,5.11.1.3 5.11.1.4	Winding, oil and hot spot temperature rises above ambient 65°C, 65°C and 80°C. Metallic parts in contact with current carrying conductors limited to 80°C.	-	Not addressed.
Nameplate information	5.12.2	Three categories Nameplate A transformer 500KVA and below and HV BIL less than 150KV Nameplate B transformer 500KVA and below not covered above Nameplate C transformers above 500KVA	7.1	There are no categories.
Nameplate information	5.12.2	Conductor material (for each winding), installation and operating instructions reference, step-up operation suitability and have a statement for no PCB.	7.1	Not required.
Nameplate information	5.12.2	Not required	7.3 b)	Impedance values for extreme taps for transformers with tapping range > ±5%
Schematic representation of windings	5.12.3	Schematic representation of single and three phase windings included.	-	Not included.

Subject Issue	ANSI / IEEE		IEC	
	Standards	Requirements	Standard	Requirements
	C57.12.00-2010		IEC 60076-1	
Bushings, CTs and thermometer well	6.1, 6.3, 6.4	Electrical characteristic of bushing below 34.5 KV included. BCTs to have ID to accommodate bushings per C57.19.01. Drawing and dimensions of thermometer well included.	-	Not addressed
Tank pressure requirements	6.5	For sealed transformer tank pressure under normal condition not to exceed 2 atmospheres (14.7 psi .	-	Not addressed.
External clearances between transformer live parts	6.8	Minimum clearance between live parts of different phases included in table 11.	-	Not addressed.
Short-circuit requirements	7.0	Short circuit duration, calculations for symmetrical, asymmetrical currents, temperature during short circuit and details of system characteristics included.	-	Not addressed.
Dimensioning of neutral connection	-	Not addressed	8.2	Dimensioned for earth –fault current for non single phase loading, for loading between phase and neutral dimensioned for load current and earth-fault current.
Load rejection of generator transformer	-	Not addressed	4.3	During load rejection able to withstand 1.4 times rated voltage for 5s at the transformer terminals.
Liquid preservation system	6.6.2	Types specified reference to C57.12.80 for description.	8.3	Different liquid preservation systems described. Free breathing or conservator, diaphragm, inert gas pressure, sealed –tank system and sealed.

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Subject Issue	ANSI / IEEE		IEC	
	Standards	Requirements	Standard	Requirements
	C57.12.00-2010		IEC 60076-1	
DC currents in neutral circuits	-	Not addressed	8.4	The sources of DC current and the consequences of DC currents in the neutral described.
Center of gravity	-	Not addressed	8.5	Center of gravity markings on two adjacent sides of the transformer
Thermal duplicate temperature-rise data	8.5	Criteria for thermal duplicate.	-	Not addressed.
Tolerance for losses	9.3	No load losses +10% Total losses +6%	9(1)	Component losses +15% (provided that the tolerance for total losses is not exceeded) Total losses +10%
Tolerances ratio	9.1	Transformer at no load 0.5% of the nameplate voltage. When the volts per turn of the winding exceeds 0.5% of the nameplate voltage, the turns ratio of the winding shall be to the nearest turn.	9(2)	At no load on principal tapping Lower of a) ± 0.5 % of specified ratio b) ±1/10 of actual percentage impedance on the principal tapping Other taps (same pair) ± 0.5% of design value of turns ratio Other taps(further pairs) ± 0.5% of design value of turns ratio

Subject Issue	ANSI / IEEE		IEC	
	Standards	Requirements	Standard	Requirements
	C57.12.00-2010		IEC 60076-1	
Tolerances impedance	9.2	Two winding transformer Impedance of transformer > 2.5% Tolerance ±7.5% Impedance ≤ 2.5% , Tolerance ±10% Three winding, zig –zag winding and auto-transformers tolerance ±10%	9(3) & (4)	Two winding transformer a) Principal tapping Impedance value is ≥ 10% tolerance ±7.5% Impedance value <10% Tolerance ±10% Any other tapping of the pair Impedance value is ≥ 10% tolerance ±10.0% Impedance value <10% Tolerance ±15% Multi-winding & auto transformer Principal tapping ±10% of specified value Any other tapping of the pair ±10% of the design value for that tapping Other pairs of winding , to be agreed but ≥ 15%
Tolerance no- load current	-	Not addressed	9 (5)	+30% of the declared value
Tests on on-load tap-changers- operation test	-	Not addressed	10.7	Operational tests on the LTC with the transformer energized and de-energized.
Check of core and frame insulation	8.2 Table 18	Measurement of insulation resistance between core and ground at 500 V DC for 1 min.	10.12	Where core and frame connections are not accessible test at 500V DC for 1 min before active part is installed in the tank. When the core and frame connections are accessible the insulation shall be tested at 2500V DC for 1 min after transformer is filled with liquid.

Subject Issue	ANSI / IEEE		IEC	
	Standards	Requirements	Standard	Requirements
	C57.12.00-2010		IEC 60076-1	
Leak , vacuum and pressure test on tank	-	Not addressed	10.8, 10.9,10.10	Details of leak, vacuum and pressure test with deflection included.
Electromagnetic compatibility	-	Not addressed	11	Transformers considered as passive elements in respect to emission of, immunity to electromagnetic disturbances.
High frequency switching transients	-	Not addressed	12	Lightly loaded and /or low power factor transformers with vacuum and SF6 interrupters may subject the transformer to high frequency transients.
Informative Annexes- Facilities for condition monitoring and environmental and safety considerations	-	Not addressed	Annex F & Annex G	Facilities for future fitting of condition monitoring systems to transformers and environmental and safety considerations included.

Comparison of Standards – ANSI / IEEE and IEC – Transformer Testing
C57.12.00-2010 section 8 & 9 and C57.12.90-2010 with IEC 600076-1 (2000) and IEC60076-3(2000)

Ajith Varghese / Waukesha Electric Systems

Subject Issue	ANSI / IEEE		IEC	
	Standards	Requirements	Standard	Requirements
Test General				
- Routine Test	C57.12.00 Table 18	Class I (69 KV and below) : Ratio-Polarity winding Resistance Positive Seq Impedance , Load loss No load loss and current Low frequency Dielectric Tests Operation of all devices Leak test Class II (115 KV through 765KV): Ratio-Polarity winding Resistance Insulation PF Core Megger Winding Megger Positive Seq Impedance , Load loss Zero Sequence Test Partial Discharge , Lightning Impulse Low frequency Dielectric Tests Low frequency test on control wiring / CT Operation of all devices Leak test DGA >=345KV : Switching Impulse	IEC 60076-1 10.1.1 & IEC60076-3	 Ratio Polarity Winding Resistance Zp , Load loss No load loss and current Routine Dielctric Tests * Tests of Tapchanger * Um <=72.5 KV Short duration AC (ACSD) Separate source 72.5 KV < Um <=170 Lightning Impulse Short duration AC (ACSD) Separate source 170 KV < Um <=300 Lightning Impulse Switching / ACSD Long duration AC (ACLD) Separate source Um >=300 Lightning Impulse Switching Long duration AC (ACLD) Separate source

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Subject Issue	ANSI / IEEE		IEC	
	Standards	Requirements	Standard	Requirements
- Design Test / Type Tests	Table 21	Sound Test Temperature rise Pressure Test	10.1.1 2	Temperature rise Dielectric type test
- Other tests / Special Tests	Table 21	Class I : Insulation PF Core Megger Winding Megger Short circuit , Sound Test , Single Ph excitation test Switching Impulse, FOW, Low frequency test on control wiring / CT Temperature rise DGA Class II : Short circuit , Sound Test , Switching Impulse (< 345KV) FOW Temperature rise	10.1.1	Sound Test Insulation PF Zo Short circuit Control losses Harmonics Megger and/or Tan delta

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Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
Tolerances				
Ratio	C57.12.00 9.1	1. Within +/-0.5 % of Name plate for all 2. for Volts per turn exceed 0.5 % of NP voltage , turn ratio of winding shall be the nearest turn	IEC60076-1: 1993 9	Rated tap : Lower of a) +/0 0.5 % of declared ratio b) +/- 1/10th of actual impedance of Rated tap Other Tap : agreement between supplier and buyer but not lower than a and b
Impedance	C57.12.00-9.2	Two wdg with Z > 2.5 % = +/- 7.5 % Z < 2.5 % = +/- 10 % Three / Zig Zag , Auto Z > 2.5 % = +/- 7.5 % Z < 2.5 % = +/- 10 % (of specified values)	IEC60076-1: 1993 9	Two wdg / first pair of multi wdg (Principal Tap) Z > 10 % = +/- 7.5 % Z < 10 % = +/- 10 % Two wdg /first pair of multi wdg (other Tap) Z > 10 % = +/- 10 % Z < 10 % = +/- 15 % Auto / second pair of multi wdg (Principal Tap) = +/- 10 % Auto / second pair of multi wdg (other Taps) = +/- 15 % (of declared values)
Losses	C57.12.00-2006 9.3	No load – not to exceed 10 % of specified Load loss – not to exceed 6 % Not a criteria for rejection	IEC60076-1: 1993 9	Total losses : + 10 % with individual components less than + 15%
No load current		No mention		+30 % of declared values

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Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
General				
Test Sequence	C57.12.90 sec 4.3 & sec 10.1.5.1	Lightning impulse and switching impulse (when required) shall precede low frequency . Having Heat run and losses ahead of dielectric has advantage of low risk of damage , but sequence is flexible		
Ratio	C57.12.00 sec 8.3.1	At all position of DETC to Rated LTC All LTC position to Rated DETC	IEC 60076-1 10.3	Measure for each tapping
	C57.12.90 sec 6.	Detailed method of how to test polarity and phase relationships is included		
Resistance Measurement				
Test environment	C57.12.90-2006 5.1.2	Measure cold resistance after minimum 3 hours with no excitation and current in winding. (1 hr for trf with pumps) Top & BTM difference shall not exceed 5 degree	IEC60076-1: 1993 10.2.3	Measure cold resistance after 3 hour minimum with no excitation
Measurement method	5.3	Bridge and Volt-amp method		No methodology specified
Loss Accuracy requirement	C57.12.90/C57.12.00 9.4	Correction for Temp and phase angle error is provided		

Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
No load test				
Waveform correction	C57.12.90- 8.3	P_C (Tm) = P_m /(P_1+kP_2) K = (RMS volt / Average Volt)^2 P1:P2 = 0.5	IEC60076-1: 1993 10.5	P_0 = P_m (1+d) d= (RMS volts – Average Volt) /RMS volts
Maximum Waveform correction	C57.12.90- 8.3	Max magnitude of correction : 5 %	IEC60076-1: 1993 10.5	Max difference in Voltmeter reading shall be below 3 %
Ambient for No Load test	C57.12.90- 8.4	Average oil within +/- 10 deg of reference temp (20 ^{0}C). Difference between top and Bottom oil temp does not exceed 5 ^{0}C Empirical formula is provided for correction outside the range	IEC60076-1: 1993 10.5	Approximately at factory ambient temp No Temperature correction
Measurement of harmonics		No Requirements	IEC60076-1: 1993 10.6	Required to be measured as percentage of fundamental components – No limits
Frequency for testing	C57.12.90- 8.2.4	Test source frequency shall be under +/- 0.5 % of rated frequency. Correction for 50/60 Hz in Annex B	IEC60076-1: 1993 10.5	Rated frequency – No tolerance specified.
Excitation current	C57.12.90- 8.5	Expressed in per unit or % of rated line current (lowest rating)		

Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
Load loss & Impedance				
Min Load current			IEC60076-1: 1993 10.4	50 % of rated current
Ambient conditions for test	C57.12.90-9.3	Top and Btm Oil difference not to exceed 5^0 c. Frequency of test source within +/- 0.5 % of nominal	IEC60076-1: 1993 10.4	Top and Btm Oil difference shall be small
Impedance on Other Taps	C57.12.00-Table 19	Extreme tap measurement required on first unit.	IEC60076-1: 1993 10.4	If tapping range exceed +/- 5 % , impedances on two extreme taps are also required
Methods of measurement	C57.12.90 9.3	Detailed Methodology provided		References IEC 60606
Zero Sequence Test				
Unit of measure	C57.12.90-2006 9.5.1	Reported in % of KVA base	IEC60076-1: 1993 10.7	Expressed in ohms per phase
Test procedure for windings with two neutral	C57.12.90-2006 9.5.3	Minimum of three tests are specified to arrive Z1 , Z2 , Z3	IEC60076-1: 1993 10.7	Testing based on agreement between manufacturer and purchaser.

Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
Tests on Tap changer		No Test Procedure and acceptance criteria is defined	IEC60076-1: 1993 10.8	Deenergized 8 cycles ; denergised 85 % Aux Voltage 1 cycle ; energized 1 cycle ; rated current – 10 opeartions across reversing/coarse-fine tap
EMC		No Test Procedure and acceptance criteria is defined.	IEC60076-1: 1993 11	Transformer is considered as passive but accessories may be . But no guideline of handling or test required is provided.
Insulation Power factor Test	C57.12.90-10.10	Test Procedure is outlined , no limits Measure between 10 and 40 C (close to 20) . temp Correction factor removed from 2010 std		Not listed
Insulation Resistance Test	C57.12.90-10.11	Test Procedure is outline , no limits Correction table for Temp is included		Not listed
Single Phase Excitation Test		No Procedure is outlined , though it is listed as other test in C57.12.00		Not listed
Control wiring megger	Table	1.5 KV AC 60 Hz , CT @ 2.5 KV	IEC60076-3: 2000 9.0	2 KV for 1 minute

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Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
Dielectric Test General				
Ambient	C57.12.90-10.1.5.2	Temp assumed at normal operating condition or condition of routine test	IEC60076-3: 2000 4	Approximately at ambient , but not lower than 10^{0} C
Dielectric level for unit in service		Class I : 85 % of test level or 150 % operating stress . Class II : Not more than 150 % - 5 min; 140 % -12 min ; 130 % - 36 min ; 120 % -120 min	IEC60076-3: 2000 9.0	80 % of Original Value
Applied Voltage (Separate source)	C57.12.90-2006 10.6.	No significant difference except Voltage levels (Note : Test levels and BILs comparisons are covered under C57.12.00 comparison)	IEC60076-3: 2000 11.0	No significant difference except Voltage levels

Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
Induce Test				
Duration Class I IEEE / ACSD IEC	C57.12.90 10.7.1	7200 cycle (same as IEC only for 60 Hz) Min test time : Not specified (max test freq) Max Test time : 60 sec	IEC60076-3: 2000 12.1	120 X Rated Freq / Test frequency, Min test time : 15 sec Theoretical Max test time : 120 sec (when Rated freq and test frequency are same)
Class II	C57.12.90 10.8.5	PD Acceptance limit :500 pC @ approx Ph-Ph Volts of 1.5 X Um	IEC60076-3: 2000 12.2.2	PD Acceptance limit :300 pC @ ph-ph Volts of 1.3 X Um (1.2 Um incase of Um > 420 KV) PD Acceptance limit :100 pC @ 1.1 X Um
Non Uniform Insulated windings		Not defined	IEC60076-3: 2000 12.2.2	Two tests required : 1. Phase to Earth 2. Phase to phase

Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
Impulse				
Lightning Sequence (Line)	IEEE C57.12.90 10.3	Line RFW, CW , CW , FW	IEC60076-3: 2000 13.2	RFW , FW , FW , FW
Impulse Tap	IEEE C57.12.90 10.3.2.4	Minimum effective turns in the winding under test.	IEC60076-3: 2000 8.0	Tapping range is +/- 5 % or less : Principal Tap Tapping range is larger than +/- 5 %: Principal Tap & two extremes
Lightning Sequence (Neutral)	IEEE C57.12.90 10.3.3	Line RFW, FW , FW (for 200 BIL and above per IEEE C57.12.00 5.10.7.1)	IEC60076-3: 2000 7.4.2 /7.4.3	Directly Earthed Neutral : Not Recommended Not directly earthed : Impulse verified by either direct method and indirect method.
Chopping time	C57.12.00-2006 Table 6	> 110 BIL : Min 3 us ; 125 BIL : Min 2.3 < =110 BIL class 2: Min 2 us 95 BIL class I : Min 1.8us < 95 BIL class I : 1.5 us	IEC60076-3: 2000 14.2	Between 2 and 6 microsecond
Switching Sequence	IEEE C57.12.90 10.2.1	Line RSS, SS , SS	IEC60076-3: 2000 14.2	RSS , SS , SS, SS
Switching Sequence (polarity)	IEEE C57.12.90 10.2.2.1	negative	IEC60076-3: 2000 15.1	negative

Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
Sound Test	C57.12.90-13		60076-10 (2001-05)	
Test Method	C57.12.90-13.1.1	Sound Pressure levels – A weighted, octave , discrete frequency	60076-10 (2001) sec 5.0	Both Sound Pressure and Sound Intensity are Valid and is to be agreed between manufacturer and purchaser
Load Condition	C57.12.90-13.3.3	No Load	60076-10 (2001) sec 6.1	To be agreed between manufacturer and purchaser
Test Tap	C57.12.90-13.3.4	Principal unless agreed differently	60076-10 (2001) sec 6.2	Principal unless agreed differently
Measurement contour	C57.12.90-13.4.1	0.3 m for sound producing surface 2 m for fans One measurement at half height for 2.4 m and below ; two at 1/3 and 2/3 for higher. Microphone 2 meter apart ; min 4	60076-10 (2001) sec 8	0.3 m for sound producing surface 2 m for fans One measurement at half height for 2.5 m and below ; two at 1/3 and 2/3 for higher. Microphone 2 meter apart ; min 6
Rated / Reduced Current Test		No methodology provided	60076-10 (2001) sec 6.3	Load test by short Circuiting one winding . Log addition of NL and Load sound to arrive at sound during operation . Not Required if " 39+ 18 (log MVA) " is 8 dB lower than guarantee
Sound Intensity Measurement		Not defined	60076-10 (2001) sec 12	Allow sound intensity measurement
Sound Power level		Not defined	60076-10 (2001) sec 12	Formula is provide to estimate Sound Power level based on pressure or intensity measurement
Ambient sound correction	C57.12.90-13.3.1(table 7)	Allows 0 to -1.6db correction for ambient to transformer sound difference of 10 to 5 db	C57.12.90-2006 13.4.1	If the difference is between 3db and 8 db , correction is applied based on formula involving ambient to tested sound level and environmental correction factor k which depend of sound reflection from surfaces.. Max allowable K is 7 db.

Comparison of Standards – IEEE and IEC
DGA during Factory (Temperature Rise) Tests of Mineral Oil Immersed Electrical Equipment
H Moleski / SD Myers Inc.

Subject Issue	IEEE		IEC	
	Standards	Requirements	Standard	Requirements
	C57.130/D17 (2006)		**61181 (2007)**	
- Scope of document	1.1	Mineral-oil filled transformers & reactors	1	Mineral-oil filled new power transformers, reactors ad instrument transformers
- Factory tests	1.2	• Factory temperature rise tests (C57.12.90) • No data from overload temperature rise tests – may or may not be applicable. (IEEE C57.119)	1	• Temperature-rise (heat run), overloading tests – power transformers & reactors • Impulse tests – instrument transformers
- Basis of gas levels – Data	1.2 6.3	• 95% confidence with "limited database" • Oil volume and voltage rating were not factors taken into account	1 2 Annex A	• References CIGRE reports • References other IEC documents • Gas generation rates given are values observed in 90% of the xfmrs tested
-Use of standard	1.2	• Guidance document – acceptable levels should be made by user and manufacturer • Trial use	1	• Specifically for long-term dielectric tests • electrical and acoustic methods more sensitive than DGA before and after short-term dielectric tests
- Oil sample collection	3	Sample in accordance with ASTM D3613, duplicates are preferred	4.1	Sample in accordance with IEC 60567, duplicates are preferred
- Oil sample containers			4.2	• Gas-tight glass syringe fitted with three-way sampling cock • Other containers that conform to IEC 60567
- Oil sample location	5.2	Near the direct path of the cooling oil. If not possible, the bottom drain valve	4.3	• Power xfmrs – ground level pipes circulating oil through radiators • NOT BOTTOM VALVE of TANK
- Drain amount before sample collection			4.3	• Syringe - At least 2 liters • Bottles – twice the volume of bottle or 5 liters

Comparison of Standards – IEEE and IEC
DGA during Factory (Temperature Rise) Tests of Mineral Oil Immersed Electrical Equipment
H Moleski / SD Myers Inc.

Subject Issue	IEEE		IEC	
	Standard	Requirements	Standard	Requirements
	C57.130/D17 (2006)		**61181 (2007)**	
- Sampling frequency	5.3	• Before the temperature rise test • After the load is shut down or 2 to 6 hours after the load is shut down. • Intermediate sampling during test	4.4	• Thermal tests on power xfmrs – before & after test. Intermediate sample frequency is left to the user to decide. • Suggested stages of sampling - After filling xfmr with oil - 1 day to 1 week after filling - Before start of thermal test - Every 2 hrs during test - End of test - 24+ hrs after test is complete • Impulse tests on instrument xfmrs – before chopped lightning-impulse test and 72 hrs after the test
- Sample labeling			4.5	• Identification of equipment • Date and time of sampling • Nature of factory test • Sampling point • Top oil temperture
- Sample storage	6	Samples should be analyzed asap, preferably within 24 hours.	4.6 6	• Shield from direct sunlight • Samples should be analyzed asap and no later than seven days after sampling

Comparison of Standards – IEEE and IEC
DGA during Factory (Temperature Rise) Tests of Mineral Oil Immersed Electrical Equipment
H Moleski / SD Myers Inc.

Subject Issue	IEEE		IEC	
	Standard	Requirements	Standard	Requirements
	C57.130/D17 (2006)		**61181 (2007)**	
- factors affecting gassing rate during thermal tests			5	• Design of windings, leads, magnetic circuit and structural elements • Oil to cellulose ratio • Paper type • Oil type • Paints, glues, material of some xfmrs • Cooling method and efficiency • Test duration
- Gases to measure during DGA	3	• Hydrogen • Methane • Ethane • Ethylene • Acetylene • Carbon monoxide • Carbon dioxide • Oxygen • Nitrogen	6	• Hydrogen • Hydrocarbons • Carbon monoxide • Carbon dioxide • Oxygen • Nitrogen
- Acceptable concentrations	3	• Acetylene must be none detected		
- Detection limits for factory tests		•	6	• Hydrogen 2 ul/l • Hydrocarbons 0.1 • Carbon monoxide 5 • Carbon dioxide 10 • Oxygen 500 • Nitrogen 2000
- Analysis methods	4	ASTM 3612	6	IEC 60567 gas chromatography Several adaptations are recommended from the 60567 methods (Toepler and partial degassing)

Comparison of Standards – IEEE and IEC
DGA during Factory (Temperature Rise) Tests of Mineral Oil Immersed Electrical Equipment
H Moleski / SD Myers Inc.

Subject Issue	IEEE		IEC	
	Standard	Requirements	Standard	Requirements
	C57.130/D17		**61181**	
- Determination of generated component concentrations	6.1	Initial minus final concentration in ppm • $\{H_2\}=H_{2\ initial} - H_{2\ final}$ • $\{HC\}= (CH_4+C_2H_4+C_2H_6)_{initial} - (CH_4+C_2H_4+C_2H_6)_{final}$ • $\{CO\}=CO_{\ initial} - CO_{\ final}$ • $\{CO_2\}=CO_{2\ initial} - CO_{2\ final}$	Annex B	90% typical gas concentration increases observed in **chopped lightning-impulse tests** (ul/l) • H_2 15 • CH_4 4 • C_2H_4 1 • C_2H_6 1.5 • C_2H_2 0.5 • CO 15
- Determination of average generation rates	6.2	Generation rates are determined by dividing the volume (ppm) of each component by the heat run interval in hours ($t_f - t_0$) • $[H_2]=\{H_2\}/t_f - t_0$ • $[HC]=\{HC\}/t_f - t_0$ • $[CO]=\{CO\}/t_f - t_0$ • $[CO_2]=\{CO_2\}/t_f - t_0$	Annex A	*Note: IEC includes acetylene in the hydrocarbon total and state that it is typically not generated during the tests* $C_n = CH_4+C_2H_4+C_2H_6+C_2H_2$
- Application of Gas generation rate guidelines	6.3	Applicable to xfmrs built in accordance with IEEE stds • 65°C AWR • 65°C TOR • 80°C HSR with an average ambient temp of 30°C		
- Gas generation rate guidelines	6.3	Condition 1 (no problem detected) **ppm/hr** • $[H_2]$ <0.8 • [HC] <0.5 • [CO] <2.0 • $[CO_2]$ <20.0	Annex A	90% typical rates of gas in modern **power transformers** during **thermal tests ul/l/h** • H_2 0.1 – 1.3 • C_n 0.04 – 0.3 • $C_n + H_2$ 0.1 – 1.6 • CO 0.4 – 2 • CO_2 5 – 18

Comparison of Standards – IEEE and IEC
DGA during Factory (Temperature Rise) Tests of Mineral Oil Immersed Electrical Equipment
H Moleski / SD Myers Inc.

Subject Issue	IEEE	IEC		
	Standard	Requirements	Standard	Requirements
	C57.130/D17 (2006)		**61181 (2007)**	
	6.3	Condition 2 (possible problem) Test duplicate sample. Investigate cause by reviewing temperature rise results. Extend test duration. • $[H_2]$ ≥0.8, <1.5 • [HC] ≥0.5, <1.0 • [CO] ≥2.0, <5.0 • $[CO_2]$ ≥20.0, <40.0	Annex A	90% typical rates of gas in modern **shell type transformers** during **thermal tests ul/l/h** • H_2 0.1 – 1.3 • C_n 0.04 – 0.3 • $C_n + H_2$ 0.1 – 1.6 • CO 4 • CO_2 5 – 18
	6.3	Condition 3 (certain problem) Mfg and customer conference. A thermal fault exists. Corrective action and repeat temperature rise tests. • $[H_2]$ ≥1.5 • [HC] ≥1.0 • [CO] ≥5.0 • $[CO_2]$ ≥40.0	Annex A	90% typical rates of gas in modern **special cases** (material compatibility problems such as paint) during **thermal tests ul/l/h** • H_2 0.7 • C_n 0.5 • $C_n + H_2$ 2.2 • CO 5 • CO_2 20
Report should include the following			7	• Testing laboratory • Identification of equipment tested • Sampling location • DGA results on each sample, in ul/l or umol/l (total volume of gas, oxygen and nitrogen may conveniently be expressed in percent of oil volume) • Rate of generation of gases in ul/l/h

Comparison of Standards – IEEE and IEC
DGA during Factory (Temperature Rise) Tests of Mineral Oil Immersed Electrical Equipment
H Moleski / SD Myers Inc.

Subject Issue	IEEE		IEC	
	Standard	Requirements	Standard	Requirements
	C57.130/D17 (2006)		**61181 (2007)**	
Follow up of cases with problems during or after put back in service. Core-type power transformers (ul/l/h)			Annex A	**C_n+H_2** **Total #** **# problem cases** • <0.5 215 1 • 0.5 – 1 36 1 • 1 – 2 21 4 • 2 – 5 12 4 • 5 – 10 4 2 • >10 3 3

Comparison of Standards – ANSI / IEEE and IEC – High Temperature Liquid-Immersed Transformers

R. P. Marek / DuPont Energy Solutions

Subject Issue	ANSI / IEEE		IEC	
	Standards	Description / Requirements	Standard	Description / Requirements
	Std 1276		TS60076-14	
General	Title	Guide	Title	Technical Specification (similar to IEEE "Trial Use" document)
	Scope	Applies to power transformers insulated with mineral oil	Scope	Applies to standard and convertor transformers larger than 1 kVA, insulated with mineral oil, silicone oil or ester liquid
Definitions		**Not defined**	3.5	**conventional** adjective that refers to temperature rise limits and insulation materials applied in systems consisting of mineral oil and non-thermally upgraded paper
	3.5	**high-temperature:** Used to describe materials, insulation systems, and transformers that are designed to operate at a maximum hottest-spot temperature above 120 °C.	3.7	**high-temperature** refers to temperature rise limits and insulation materials applied in systems consisting of solid materials and/or liquid operating at higher temperatures than conventional
	3.6	**high-temperature insulation system:** An insulation system composed of all high-temperature solid insulation materials, with or without high-temperature fluids.		**Not defined**

Subject Issue	ANSI / IEEE		IEC	
	Standards	**Description / Requirements**	**Standard**	**Description / Requirements**
	Std 1276		**TS60076-14**	
	3.8	**hybrid high-temperature insulation system:** An insulation system usually composed of high-temperature solid insulation material adjacent to winding conductors and cellulose materials in the areas where the maximum temperature at rated load does not exceed 120 °C. This system typically uses conventional mineral oil as the insulating liquid.	3.8	**hybrid insulation system** high-temperature solid insulation material adjacent to all winding conductors either bare or insulated (including all conductor insulation, spacers, strips and cylinders in direct contact with the winding conductor) and cellulose-based materials in lower temperature areas where thermal class 105 limits are met
		Not defined	3.9	**semi-hybrid insulation system** high-temperature materials used only for conductor insulation
		Not defined	3.10	**mixed insulation system** high-temperature solid insulation material adjacent to the winding conductors located in the hotter regions (including all conductor insulation and, if necessary, spacers, strips and cylinders in contact with these conductors) and cellulose-based materials in the rest of the winding and other lower temperature areas where thermal class 105 limits are met

Subject Issue	ANSI / IEEE		IEC	
	Standards	**Description / Requirements**	**Standard**	**Description / Requirements**
	Std 1276		**TS60076-14**	
		Not defined	3.11	**homogeneous insulation system** high-temperature insulation used in all areas exposed to temperatures higher than would be suitable for conventional insulation systems together with high-temperature insulating liquid
Insulation information		No equivalent	Table 1	**Typical properties of solid insulation materials**
	5.6	High-temperature solid and wire insulation and their interaction with mineral oil and other high-temperature fluids	Table 2	**Typical enamels for wire insulation**
		No equivalent	Table 3	**Typical performance characteristics of unused insulating liquids**
Temperature limits	Table 1	**Maximum temperature limits for various (hybrid) insulation systems**	Table 4a	**Temperature limits for transformers with mineral oil or alternative liquid operated at 60 K top liquid temperature rise a. Maximum temperature rise limits**
		No equivalent	Table 4b	**b. Maximum overload temperature limits**

Subject Issue	ANSI / IEEE		IEC	
	Standards	**Description / Requirements**	**Standard**	**Description / Requirements**
	Std 1276		**TS60076-14**	
		No equivalent	Table 5a	**Temperature limits for transformers with homogeneous high-temperature insulation systems** **a. Maximum temperature rise limits**
		No equivalent	Table 5b	**b. Maximum overload temperature limits**
Insulation-system temperature ratings for high-temperature rise systems	5.2	Bubble generation	Annex A	Calculation of bubble generation temperature
Aging test procedure for material qualification	5.4	Defines TUK life curve for cellulose and criteria for paper and enamel	3.6	**thermally upgraded paper (TUP) …**
Loading information	6.0	Loading guides for high-temperature transformers	8.4	Overload
Transformer accessories and compatibility		No equivalent – not necessary since all accessories interface with mineral oil operating at normal temperatures	7.0	General notes about high-temperature application
		No equivalent	8.0	Special design considerations - General notes on high-temperature application - maximum permissible short circuit temperature for category I transformers with high-temperature liquids covered by Table 5 is 350 °C.
Required information	7.0	Description of high-temperature transformers – mostly for repair units	9.1	Information to be provided by the purchaser

Subject Issue	ANSI / IEEE		IEC	
	Standards	**Description / Requirements**	**Standard**	**Description / Requirements**
	Std 1276		**TS60076-14**	
		No equivalent	9.2	Information to be provided by the manufacturer
Nameplate information	8.0	Nameplate information Additional information required for high-temperature	10.0	Rating plate and additional information
Testing	9.0	Heat run test and average winding temperature	11.0	Testing
Gas analysis	Annex A	Gas analysis		No equivalent

Synonyms

IEEE C57.131 (Revision)	IEC 60214-1 (Current Version)	Definition
Arcing switch	Diverter switch	A switching device used in conjunction with a tap selector to carry, make, and break current in circuits that have already been selected.
Arcing tap switch	Selector switch	A switching device capable of carrying current and also breaking and making current while selecting a tap position. It, thereby, combines the duties of a diverter switch and a tap selector.
De-energized tap changer (DETC)	Off-circuit tap changer	A device for changing the tap of a winding, suitable for operation only when the transformer is de-energized.
Externally mounted tap changer	Air environment tap changer	A tap changer mounted in a container outside the main transformer tank and immersed in its own insulating liquid.
Internally mounted tap changer	liquid environment tap changer	A tap changer mounted inside the main transformer tank and immersed in the insulating liquid of the transformer
Load tap changer (LTC)	On-load tap changer (OLTC)	A device for changing the tap of a winding, suitable for operation while the transformer is energized or on load.
Reversing switch	Reversing change-over selector	A change-over selector that connects one or the other end of the tap winding to the main winding.

. C57.131-1995 Vs. IEC 60214-1 Comparison

Bill Henning / Waukesha Electric Systems

The definition of *step voltage* given in IEC 214 (1989) and IEC 60214-1 is: "The *step voltage* is the voltage between adjacent tap changer terminals."

IEEE C57.131-1995 provides a slightly different definition of the term *step voltage,* shown below.

> Rated step voltage (according to C57.131-1995):
>
> For each value of rated through current, the highest permissible voltage between successive tap positions.
>
> NOTE : Step voltage of resistance type LTCs means tap to tap voltage (no bridging position).

The IEC definition clearly defines step voltage in terms adjacent (tap changer) terminals, while the IEEE definition refers to tap positions. This ambiguity is being addressed in the current revision of C57.131.

Key Differences between C57.131-1995 and IEC 60214-1

Terminology: Fluid versus Liquid

IEC 60214-1 uses the term *liquid* whereas C57.131-1995 uses *fluid* in all references to the insulating medium.

Scope

In addition to LTCs, IEC 60214-1 covers de-energized tap changers (DETCs). C57.131-1995 does not cover de-energized tap changers.

Short Circuit Current Test

IEC 60214-1 places a tolerance of ±10% on the 2 second duration of the test current. C57.131-1995 requires a 2 second duration but does not place on tolerance on the duration.

Transition Impedance Test

IEC 60214-1 provides a limit of 350 ºC for the resistor in internally mounted LTCs and a limit of 400 ºC for externally mounted LTCs. C57.131-1995 places a limit of 350 ºC period. (No distinction between internally or externally mounted LTCs)

Bill Henning / Waukesha Electric Systems

Mechanical Endurance Test

IEC 60214-1 states that at least 50,000 tap change operations shall be carried out on the change-over selector. C57.131-1995 gives this number as 15, 625 operations of the change-over selector.

Tightness Test

IEC 60214-1 specifies a tightness test to assure that dissolved gases due to arcing in the tap changer compartment do not enter the transformer main tank and effect DGA results. C57.131-1995 does not require this test.

Auxiliary Circuits Insulation Test

IEC 60214-1 requires that this test be done at 2.0 kV. C57.131-1995 requires that this test be done at 1.5 kV.

C57.131 Annex Information

Annex A Switching Duty Relating to Load Tap Changers with Resistor Transition

This annex shows phasor diagrams of the voltages and currents during tap change operations for flag cycle and pennant cycle types. A table (Table A.1 Duty on Main and Transition Contacts for Resistance Type LTCs) indicates the current and voltage magnitudes, corresponding to the phasor diagrams, for the current switched and the recovery voltages across the various contacts during tap change operations for flag cycle and pennant cycle, arcing switch and arcing tap switch constructions. These tables for C57.131-1995 and IEC60214-1 are identical, except that IEC60214-1 has one additional major row for a selector switch with asymmetrical pennant cycle (1 resistor). C57.131-1995 does not contain this row of information.

Comparison of Standards – ANSI / IEEE and IEC – Temperature Rise

H Nordman / ABB Transformers

Subject Issue	ANSI / IEEE		IEC	
	Standards	Requirements	Standard	Requirements
Temperature Rise Limits	**C57.12.00-2010 C57.12.90-2010**		**IEC 60076-2: 2011**	
- Tap position	5.11.1.1	Max. average winding temperature rise tapping = Highest loss tapping Ditto for the winding hot-spot rise	6.2	- Tapping range ≤ ±5% and S_r ≤ 833 kVA/phase: Principal tapping - Tapping range >±5% or S_r > 833 kVA/phase: Max. temperature rise tapping
- Ambient temperature		**Not addressed. In other parts of IEEE: 30 °C**	**6.2**	**20 °C yearly average**
- Top oil rise	5.11.1.4	65 K	6.2	60 K
- Average winding rise, non-upgraded insulation				
* ON and OF * OD		Not addressed Not addressed	6.2 6.2	65 K 70 K
- Average winding rise, upgraded insulation				
* ON and OF * OD	5.11.1.1 5.11.1.1	65 K 65 K	6.2 6.2	65 K 70 K
- Winding hot-spot rise				
* non-upgraded insulation * upgraded insulation	 5.11.1.1	Not addressed 80 K	6.2 6.2	78 K 78 K
- Rises of metallic parts other than windings	5.11.1.3	- Parts in contact with current carrying conductor insulation: 80 K - Other parts: "shall not attain excessive temp. rises at rated load"	6.2	"...shall not reach temperatures which will cause damage to adjacent parts or undue aging of the insulation liquid."
- Reduction of Temperature Rise Limits				
* Altitude correction for over 1000 m	11.4.3	Temperature rises increased by Equation (32)	6.3.1	- Limit reduced by 1 K / 400 m for ...AN - Limit reduced by 1 K / 250 m for ...AF
* Elevated ambient temperatures		Not addressed	6.2	Limits reduced by the same amount as the excess of 20 ° - 10 K for amb. temp. 30 °C etc.

Comparison of Standards – ANSI / IEEE and IEC – Temperature Rise

H Nordman / ABB Transformers

Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
Temperature Rise Test, Ambient Temperature	**C57.12.90-2010**		**IEC 60076-2: 2011**	
- Test room air temperature, ..AN, ..AF	11.3.1.1	Air between 10 °C and 40 °C	7.2.1	- Air between 10 °C and "the maximum ambient temperature for which the transformer is designed"
- Cooling water temperature, ..WF	11.3.1.2	Water between 20 °C and 30 °C	7.2.2	Water between 5 °C and "the maximum water temperature for which the transformer is designed"
- Number of sensors, ..AN, ..AF	11.3.1.1	At least 3 sensors	7.2.1	At least 4 sensors (for large units 6 sensors)
- Height level of sensors, ..AN; ..AF	11.3.1.1	"about mid-height of the transformer" "1 m to 2 m from the transformer"	7.2.1	...AN: "about halfway up the cooling surfaces and about 2 m from the perimeter of tank and cooling surfaces" ...AF: "in the air at about 0.5 m from the intake of the coolers"
- Location of sensors, ..WF	11.3.1.2	"the temperature of the incoming and outgoing water, shall be measured"	7.2.2	"temperature shall be measured at the intake of the cooling equipm."
Temperature Rise Test, Total Loss Phase	**C57.12.90-2010**		**IEC 60076-2: 2011**	
- Steady state criterion	11.3.2	Top liquid temperature rise variation below 2.5 % or 1 K, whichever is greater, during consequtively 3 h	7.3.2	Change of top liquid temperature below 1 K / h during 3 h
- Measurement of top oil temperature	11.3.2	One sensor 50 mm below top liquid surface	7.4.1	- Measurement in the pockets: < 6.7 MVA / phase $\Rightarrow$ 1 pocket 6.7 MVA / phase $\leq S_r < 33$ MVA / phase $\Rightarrow$ 2 pockets ≥ 33 MVA / phase $\Rightarrow$ 3 pockets - Or by agreement: As an average of the pockets and the liquid in the centre of the pipes to the cooling equipment

Comparison of Standards – ANSI / IEEE and IEC – Temperature Rise

H Nordman / ABB Transformers

Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
Temperature Rise Test, Total Loss Phase	**C57.12.90-2010**		**IEC 60076-2: 2011**	
- Measurement of bottom oil temperature				
* Transformers with external coolers	11.3.2	One sensor in an inlet pipe from a common header or from one radiator in the middle of the bank	7.4.2	Sensors fitted in one or several bottom pipes (if there are more than one pipe)
* Transformers without external coolers (plain or corrugated tanks)	11.3.2	"thermocouples on the tank wall at the elevation of the bottom of the winding"	7.4.2	Not addressed
- Determination of average oil temperature rise				
* Transformers with external coolers	11.3.2	Top oil temperature rise – 0.5 x (Top pipe – Bottom pipe)	7.4.2	Average of top and bottom oil temperature rises
* Transformers without external coolers (plain or corrugated tanks)	11.3.2	Top oil temperature rise – 0.5 x (Tank surface at winding top – Tank surface at winding bottom)	7.4.2	0.8 x Top oil temperature rise
- Multi-winding transformers		Not addressed	7.2.3	Supply the losses of 3 windings into 2 or 3 windings to obtain the oil temperature rises
Temperature Rise Test, Rated Current Phase	**C57.12.90-2010**		**IEC 60076-2: 2011**	
- Average winding temperature measurement	11.2.2	Shall be made on all phases	7.6	Shall be made on one phase (preferably middle limb)

Comparison of Standards – ANSI / IEEE and IEC – Temperature Rise

H Nordman / ABB Transformers

Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
Temperature Rise Test, Rated Current Phase	**C57.12.90-2010**		**IEC 60076-2: 2011**	
- Warm Resistance Curve, shutdown procedure	11.2.2	- The first valid resistance value has to be taken within 4 min. after shutdown - At least four resistance measurements shall be made on one terminal pair - Fans and cooling water shall be shut off. Oil pumps may be shut off or left running	7.6 and 7.7	- No minimum time for the first valid value is given in the main body. Annex C (informative) recommends: * within 2 min. for transf. < 33 MVA / phase * within 3 min. for transf . ≥ 33 MVA / phase to 167 MVA / phase * within 4 min. for transf . ≥ 167 MVA / phase - If fans and pumps are operating during the test, they should be maintained during the measurements
- Determination of average winding rise	11.3.3	- Average winding rise can be either based on the gradient to top oil or to average oil - Factors 234.5 °C for Cu and 225.0 °C for Al (up to 230 °C for alloyed Al)	7.6	- Average winding rise is based on average oil rise - Factors 235 °C for Cu and 225 °C for Al

Comparison of Standards – ANSI / IEEE and IEC – Temperature Rise

H Nordman / ABB Transformers

Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
Temperature Rise Test, Rated Current Phase	**C57.12.90-2010**		**IEC 60076-2: 2011**	
- Determination of winding hot-spot rise	5.11.1.1	a) Direct measurement by a "sufficient number of direct reading sensors" b) Direct measurement on an exact duplicate transformer c) Calculation by a thoroughly verified method	7.10	* Rated power < 6.7 MVA / phase neither calculation nor direct measurement is required * Rated power ≥ 6.7 MVA / phase calculation is necessary. If agreed, direct measurement can be made as a special test * For strategic asset or specific operating condition (e.g. nuclear power plant) both calculation and direct measurement can be made and the results compared Calculation: Annex B (informative) Measurement: Annex E (informative)
Temperature Rise Test, Supplied Values	**C57.12.90-2010**		**IEC 60076-2: 2011**	
- Supplied loss	11.4.2	Not less than 80 % of the required total loss	7.13	Within ±20 % from target loss (By agreement ≥ - 30 %)
- Supplied current	11.4.1	Not less than 85 % of rated winding current	7.13	Within ±10 % from target current (By agreement ≥ - 15 %)
- Supplied frequency different from transformer frequency	11.4.4 and B.3	Permitted: Formulas for frequency conversion 50/60 Hz given		Not addressed

Comparison of Standards – ANSI / IEEE and IEC – Temperature Rise

H Nordman / ABB Transformers

Subject Issue	ANSI / IEEE		IEC	
	Standard	Requirements	Standard	Requirements
Temperature Rise Test, Corrections	**C57.12.90-2010**		**IEC 60076-2: 2011**	
- Liquid exponent n	11.4.2	* 0.8 for ONAN * 0.9 for ONAF, OFAF, OFWF * 1.0 for ODAF, ODWF	7.13	* 0.8 for ONAN Distribution transformers ≤ 833 kVA/phase * 0.9 for ONAN; ONAF Medium and Large Power transformers > 833 kVA/phase * 1.0 for OFAF, OFWF * 1.0 for ODAF, ODWF
- Winding exponent y = 2m	11.4.1	* 1.6 for ONAN * 1.6 for ONAF, OFAF, OFWF * 2.0 for ODAF, ODWF	7.13	* 1.6 for ONAN * 1.6 for ONAF, OFAF, OFWF * 2.0 for ODAF, ODWF
- Hot-spot exponent z		Not addressed	7.13	* 1.6 for ONAN, ONAF, OFAF, OFWF Medium and Large Power Transformers > 833 kVA/phase * 2.0 for ODAF, ODWF
- Correction for supply frequency different from transformer frequency	11.4.4 and B.3	Formulas for frequency conversion 50/60 Hz given		Not addressed
Temperature Rise Test, DGA as a Special Test according to agreement	**C57.12.90-2010**		**IEC 60076-2: 2011**	
- Procedure and permissible limits		Not addressed	7.12	Guidance given in Annex D (informative)

IEC 60296 and IEC 60422 Comparison to IEEE C57.106-2006
Jim Thompson / T&R Service Company

Table 2 of IEC 60296, “Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switch gear,” uses 30 ppm moisture in oil as a minimum acceptance value for new mineral oil delivered in bulk tanks and 40 ppm moisture as a minimum acceptance value for new mineral oil delivered in drums. The C57.106-2006 at Table 1 uses a minimum acceptance value of 25 ppm.

Figure 1 of IEC 60422 “Mineral Insulating Oils in electrical equipment – Supervision and maintenance guidance” contains a formula with no reference for moisture solubility versus temperature and also a curve for aged oil for the same. The C57.106-2006 provides two references in section in section 4.5 for published papers to find an equation for solubility and makes reference to the fact that aged oil will have different solubility.

Table 3 of IEC 60422 uses minimum acceptance moisture in oil values for new mineral oil in equipment of 20 ppm for < 72.5 KV equipment, < 10 ppm for 72.5 KV to 170 KV equipment and < 10 ppm for > 170 KV equipment. The C57.106-2006 at Table 5 uses a minimum acceptance value for new oil of 20 ppm for < or = 69 KV equipment ; 10 ppm for > 69 KV and < 230 KV equipment; and 10 ppm for 230 KV and above equipment. The C57.106-2006 at Tables 7 and 8 for circuit breakers provide guidelines of 25 ppm for new shipments and 20 ppm after filling. The C57.106-2006 at Table 5 uses a minimum acceptance value for service aged oil of 35 ppm for < or = 69 KV equipment ; 25 ppm for > 69 KV and < 230 KV equipment; and 20 ppm for 230 KV and above equipment – and 25 ppm for circuit breakers.

Additional Notes:

IEC 60422 appears to be an acceptance criterion while C57.106-2006 is a guide with all of the precautionary statements clearly stating as such.

IEC 60422 contains references to C57.106-2002 and a memo should be sent to the IEC committee that a new guide has been published on June of 2007 (IEEE C57.106-2006).