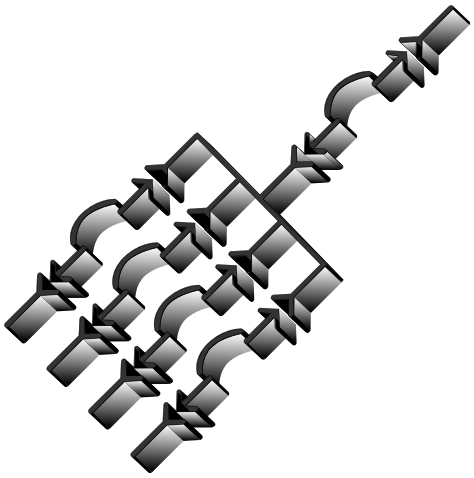
Application Note



A Comparison between ANSI/IEEE and IEC Requirements for Metal-clad Switchgear

There are a number of important differences between power systems in Europe and North America. A difference in power frequency (50 vs. 60 Hz) is obvious. Voltage levels are different, standard current ratings are different, and system kA interrupting levels are also quite different. It is common for European designers to keep continuous currents and kA levels lower by increasing the system voltage and allowing system impedance to be higher. In North America, the opposite theory seems to be often (but not always) applied.

Standards are also written differently. IEC standards often include a large number of ratings, leaving it up to the manufacturer to decide what to offer. This proliferation of ratings offers both great flexibility but also confusion – it is common that one physical product design may be re-badged into two or three “different” products just to offer a wide range. On the other hand, ANSI/IEEE standards often have a very limited number of ratings, and often clearly specify which combinations are acceptable. This can lead to some odd occurrences, such as a 1200 A minimum rating in switchgear where many loads are under 300 A, and ignoring a whole popular voltage class of equipment (25 kV class) for decades. In both cases, all ratings are subject to agreement between user and manufacturer, although only the IEC standards explicitly state so (ANSI/IEEE standards are voluntary).

There is a lot of pressure to work towards global harmonization of standards. To this end, it behooves us to understand what the differences are, so we can make intelligent decisions. This Application Note discusses the differences between the two series of standards as they apply to switchgear assemblies. It is intended to be non-judgmental, a listing of the main differences between the standards. A future discussion will cover the circuit breakers themselves. To keep it simple, the comparisons will be presented in table format, with similar topics grouped together.

Table 1
Main comparison

IEC	ANSI / IEEE	Comments
The Basics		
The standards		
IEC 298 – AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV	ANSI/IEEE C37.20.2 – IEEE Standard for metal-clad and station-type cubicle switchgear	Associated circuit breaker standards are ANSI/IEEE C37.04, C37.06, C37.09, and IEC 56. IEC has a "Common Clauses" standard IEC 694 to link standards (no equivalent in IEEE)
Scope		
IEC covers both control gear and switchgear. It discusses metal-clad, compartmented as well as cubicle type (similar to ANSI/IEEE metal-enclosed type which also requires no internal barriers).	Station type cubicle switchgear is an obsolete product, not manufactured since the early 1970's. The coverage of metal-clad equipment is applicable. No mention is made of controlgear.	
Both standards describe metal-clad switchgear as a subset of metal-enclosed switchgear. Both require a full external metal enclosure with intention to ground it.	= ditto =	
IEC requires metal-clad switchgear to have grounded metal barriers creating separate compartments for certain components.	ANSI/IEEE has more detail concerning compartmentalization of components.	
IEC covers compartmented switchgear where certain barriers may be nonmetallic	No equivalent in ANSI/IEEE	
The main switching device can be fixed or withdrawable.	The main switching device must be withdrawable.	
Busbar may be insulated or bare	Busbar shall be insulated.	
Voltage rating		
Rated voltage is the upper limit of the highest voltage of systems for which the switchgear or controlgear is intended. See Table 2 for comparison.	Rated maximum voltage is the highest rms voltage for which the equipment is designed, and the upper limit for operation. See Table 2 for comparison	
Low Frequency Power Withstand – see Table 2 for comparison	= ditto =	
Impulse Withstand – see Table 2 for comparison	= ditto =	
Isolating gap – required to be higher than the rated impulse and power frequency levels per Table 1 of IEC 694. Approximately 15 to 20 % higher than the rated levels.	Isolating gap – required to be higher than the rated impulse and power frequency levels by a flat 10 %.	Isolating gap is the break in the circuit created by withdrawing a drawout circuit breaker to the test or disconnected position, or created by the opening of a disconnect switch in series with a fixed mounted circuit breaker.

IEC	ANSI / IEEE	Comments
Current rating		
Continuous current ratings are defined in IEC 694. Some circuits are allowed to have different ratings. No reference to the ratings of the switching and interrupting devices are made.	Continuous current ratings are defined in the text of C37.20.2. The continuous current rating of the individual circuit breaker compartment shall be equal to the ratings of the switching and interrupting devices used except as modified by lower ratings of fuses, current transformers etc.	ANSI/IEEE allows 1200, 2000 and 3000 ampere ratings only. IEC allows 400, 500, 630, 600, 1000, 1250, 1600, 2000, 2500, 3150 and 4000 ampere ratings. Manufacturers do not have to supply all ratings if they do not want to of course, in either standard.
Momentary current – refers to IEC 694 for the peak withstand current (closest rating to the ANSI momentary current), which is defined as 2.5 times the rated short time current of the switchgear.	Momentary current – the rms value including the DC component at the major peak of the maximum cycle which the switchgear shall withstand for a minimum of 10 cycles. It must numerically match the close and latch rating of the circuit breaker.	In ANSI/IEEE, the close and latch has long been defined as 2.7 times the rated short circuit current of the circuit breaker. This was one of the significant differences between the two standards. ANSI has now lowered the 2.7 figure to 2.6 to more closely match practical system conditions.
Short time current – refers to IEC 694 clause 4.5. Defined as the rms value of the current that a mechanical switching device must withstand in the closed position. The standard duration is 1 second, with an alternate time of 3 seconds possible.	Short time current – the average rms current the equipment is capable of carrying for a period of 2 seconds. The short time current rating of individual components is equal to the short time current rating of the circuit breaker used.	
Frequency		
IEC lists standard rating frequencies of either 50 or 60 Hertz, but also lists additional frequencies of 16 2/3 and 25 Hertz (commonly used for electric railway systems)	AMSI/IEEE defines rated frequency of an assembly or device as the frequency for which it is designed. All ratings are based on 60 Hertz only.	
Temperature limits		
Both standards base temperature rise on a maximum 40 °C ambient. Allowable temperature rises are compared in Table 3.	=ditto =	
Current transformer ratings and accessories		
IEC does not address CT's within the switchgear standard	Covered in C37.20.2 clauses 4.6 and 4.7, including mechanical ratings, thermal ratings, ambient temperature ratings, minimum accuracy.	
1 or 5 ampere secondaries are allowed (1 amp is the most common)	Normally only 5 ampere secondaries are used	
Control voltage and frequency		
IEC refers to clauses 4.8 and 4.9 in IEC 694	ANSI/IEEE C37.20.2 does not address these requirements, although the circuit breaker standard C37.06 does	The values in IEC and ANSI/IEEE are not the same but are similar enough and are compatible in most cases.

IEC	ANSI / IEEE	Comments
Design tests		
Dielectric tests **General information**		
Refers to IEC 694, which relies on the high voltage testing standard IEC 60	Covered by C37.20.2 clause 5.2.1, which relies on the high voltage testing standard ANSI/IEEE 4.	ANSI/IEEE 4 states in its forward that it closely conforms to the IEC 60 standard.
Standard atmospheric conditions shall be achieved as close as possible.	Standard atmospheric conditions shall be met or correction factors shall be applied as indicated.	It is difficult to always meet all the standard conditions so the ANSI/IEEE rules are much easier for manufacturers to apply.
With the switching device in the connected position and closed, voltage to be applied to each phase with the other two phases and the frame grounded	= ditto =	
Testing with the switching device in the open position only required if less favourable electric field conditions result in the open or removed condition.	Voltage to be applied to each terminal with the other five terminals and the frame grounded, with the switching device in the connected position and closed	
Not required.	With the switching device withdrawn and closed, voltage shall be applied to the three incoming terminals simultaneously with the outgoing terminals and the frame grounded, then to the outgoing terminals with the incoming and frame grounded.	
A higher than normal voltage shall be applied across the isolating distance.	A higher than normal voltage shall be applied between incoming and outgoing terminals	
Some requirements to have a grounded, conductive electrode on the accessible side of an insulating barrier during voltage tests.	Not required.	
Power frequency withstand		
A one minute power frequency voltage withstand test shall be applied.	= ditto = plus requirements for rate of rise of test voltage and limits on the frequency variation.	Because of the actual tolerances permitted, the ANSI/IEEE tests allow 60 Hz equipment to be tested at 50 Hz and vice versa.
Impulse withstand		
1.2 x 50 ms full wave waveform used, positive and negative polarity	= ditto =	
Fifteen impulses of each polarity to each test configuration. A maximum of two flashovers are allowed for a successful test.	Three applications of each polarity to each test configuration. If all three good, then pass. If there is one failure, nine more shots to be applied. If all nine pass, first failure judged to be random	
Busbar insulation		
Insulated busbars not required by IEC, so no test specified	Low frequency 1 minute test at maximum rated voltage to ground.	
Wet tests on entrance bushings		
Does not require wet tests for metal-enclosed switchgear and controlgear.	Requires these tests to be performed in accordance with ANSI/IEEE 4.	

IEC	ANSI / IEEE	Comments
Partial discharge tests		
Recommended under certain circumstances but is not mandatory. No acceptable level of partial discharge is recommended.	Not required.	
Dielectric tests on auxiliary and control circuits		
1 minute 2000 volt power frequency withstand test between all auxiliary and control circuits and the enclosure.	Not required.	Both standards require this test as a routine test, but only IEC requires it also as a type test.
Continuous Current Tests **General Information**		
To be performed at the rated continuous current and at rated frequency, and temperature rises must not be exceeded.	= ditto =	
Allowable temperature rises are different (see Table 3). In general IEC allows somewhat higher temperature rises.	Permits somewhat lower temperature rises than IEC. See Table 3.	
Thermocouples or thermometers allowed	Thermocouples shall be used	
Test frequency to be not less than rated. IEC 298 references IEC 694 which allows 50 or 60Hz, but 298 also adds 16 2/3 and 25 Hz as allowable frequencies.	Test frequency to be generallly 60Hz. Allowance is made for special consideration of other frequencies although most ratings are only provided for 60Hz.	16 2/3 is a typical frequency used for traction applications.
Test can be terminated if no test point increases in temperature rise more than 1 °C in a one hour period.	Test can be terminated if no test point increases in temperature rise more than 1 °C in each of two successive half hour intervals.	
Test arrangement shall reproduce the most severe conditions of use by loading adjacent components or by adding heat sources to simulate them.	Not addressed by ANSI/IEEE C37.20.2, but is addressed partially by C37.55 (does not require loading of adjacent cells)	
Covers temperature rise testing of auxiliary equipment.	Does not address.	
Resistance of main circuit		
Refers to IEC 694 clause 6.4, and discusses measurement of the main circuit resistance both before and after the temperature rise test, although it is not clearly mandatory.	Does not address for switchgear assemblies.	
Short-time current withstand		
Requires the main circuit to withstand an AC current equal to the short time current rating for the required time.	Requires the main circuit to withstand an AC current equal to the short time current rating for the required time.	
Usually combined with the Momentary Current test below, but can be performed separately. The test shall be withstood without damage which would impair good operation of the main circuit.	Is permitted to be combined with the Momentary Current test below. The test shall be withstood without physical damage.	

IEC	ANSI / IEEE	Comments
Momentary current		
The main circuits shall withstand a peak current equal to the momentary current rating. May be combined with the Short time test. If performed separately, shall be at least 0.3 seconds duration. The test shall be withstood without damage which would impair good operation of the main circuit.	The main circuits shall withstand a peak current equal to the momentary current rating. May be combined with the Short time test. If performed separately, shall be at least 10 cycles duration. Shall be no permanent deformation of the bus bars, or if there is that the dielectric requirements can still be met.	
Short time and peak withstand tests shall be made on grounding conductors, grounding connections and grounding devices in a similar fashion to the tests on the main circuit.	No specific requirement, but C37.20.2 clause 6.1.2 requires that the ground bus withstand the rated short time current of the switchgear for 2 seconds.	
Mechanical endurance		
IEC 298 clause 6.102 requires 50 operations of switching devices and 25 insertion-withdrawal cycles of removable devices. Interlocks that control the removal of removable parts must withstand 25 attempts to remove the parts.	C37.20.2 clause 5.2.5 specifies mechanical endurance tests consisting of 100 insertion-withdrawal cycles with checking of interlocks every 10 cycles. No requirement for switching device operation.	
Insulation, primary and applied		
No requirements.	Shall test for flame resistance and tracking resistance of primary insulation, and for flame resistance of applied insulation.	
Paint		
No requirements.	Salt spray test required.	
Rain test for outdoor enclosures		
Required as described in IEC 298 clause 6.107 and Annex CC.	Required as described in C37.20.2 clause 5.2.9.	Both standards very similar in procedure and required results.
Verification of making and interrupting capacities		
Requires testing of the main switching device installed in the switchgear to meet the specified making and interrupting ratings.	No requirements.	
Verification of degree of protection		
Requires tests per IEC 529, using standard test objects to verify opening sizes, but only if there is doubt if the requirements are met.	No requirements, but Annex A of C37.20.2 describes three levels of enclosures and the conformance tests required. ANSI C37.55 does require testing to these requirements.	In IEC, this test is between the user and the manufacturer to decide if to perform.
Measurement of leakage currents		
IEC 298 clause 6.106 requires the testing of leakage currents when the switchgear contains insulating partitions or safety shutters.	No requirements.	
Resistance to the effects of internal arcing		
If agreed upon between purchaser and manufacturer, this test may be required. Tests to be performed in accordance with Annex AA of IEC 298.	No requirements as yet (an IEEE test guide is under preparation)	Canada usually uses the EEMAC G14-1 testing guide, which differs somewhat from the IEC requirements.

IEC	ANSI / IEEE	Comments
Pressure withstand and gas tightness tests		
Required tests for gas filled compartments per IEC 298 clause 6.104 and 6.105.	No requirements.	
Production testing		
Dielectric tests		
Normal power frequency tests to be applied under the same conditions and in the same way as the Type tests, except no requirement for higher than normal testing of the isolation gap, and only a test of each phase with the other phases and to ground is required.	= ditto =	
Mechanical operation testing		
Must include the circuit breakers in position in the switchgear, to be tested at their limits of operating voltage and pressures. Each switching device shall be tested in a manner similar to their design test for 5 withdraw-insertion cycles.	Requires tests to ensure proper functioning of interlocks, shutters etc. Interchangeable elements must be proven to be interchangeable. However, no details of these tests are provided, and they can be done in jigs, not the actual switchgear.	
Grounding of instrument transformer cases		
No requirement.	Requires the effectiveness of the grounding of metallically cased CT's to be tested.	
Control wiring continuity		
Requires verification that the control wiring conforms with the diagram.	Requires testing to prove the correctness of the control wiring, either by operation of the individual control devices or by continuity checks.	
Control wiring insulation tests		
Same as the type test requirements, 2000 V for 1 minute. It is allowable to reduce the time to 1 second by agreement between the manufacturer and the user.	Requires a 60 Hz test to ground, individually or in groups, and can be 1500 V for 1 minute or 1800 V for 1 second.	
Polarity verification		
No requirements	Requires tests to prove that connections between instrument transformers and meters and relays are connected with the proper polarities, and that all pointers move in the right direction.	
Sequence tests		
Requires tests on auxiliary electrical, pneumatic and hydraulic devices, operating correctly five times in succession, with the most unfavourable limit values of auxiliary supply. They must be in satisfactory condition after this test. No specific requirement exists for sequential tests on power devices.	Devices that are intended to operate in sequence function properly and in the sequence intended. Does not explicitly state this is required on both power and auxiliary devices.	

IEC	ANSI / IEEE	Comments
Resistance of main circuit		
Requires measurement of voltage drop or resistance of main circuit, subject to agreement between user and manufacturer.	No requirement.	
Partial discharge test		
Can be performed as a routine test subject to agreement between user and manufacturer. Acceptable levels are by agreement.	No requirements.	
Pressure withstand and gas tightness tests		
Required for gas filled compartments.	No requirements.	
Commissioning tests		
Required to check correct operation after the switchgear has been erected on site. A voltage test at 80% of the factory power frequency level is recommended.	C37.20.2 clause 5.5 covers field dielectric testing and specifies testing at a 75% level.	
Construction features		
Main bus requirements		
No requirements in this fashion.	Primary bus conductors and connections to be covered with an insulating material. Some details about bus construction including materials which are acceptable, phase arrangements, phase sequencing, bus splices, cable terminations etc.	
Grounding (earthing)		
Require a ground bus connecting all sections of a switchgear, and having provision to connect to the station ground.	= ditto =	Grounding is a North American (ANSI/IEEE) term, while Earthing is a European (IEC) term. We will call it grounding here for simplicity.
Ground bus shall have a cross section such that the current density does not exceed 200 A/mm2 for the specified ground fault conditions.	Ground bus shall carry the rated short time current for 2 seconds minimum	
Normally grounded parts of removable elements to be grounded before insertion into the connected position. Shall remain grounded in the test and disconnected positions.	Normally grounded parts of removable elements to be grounded before insertion into the connected position. Shall remain grounded until the primary circuit is disconnected and the removable element is removed to “a safe distance”	
Switchgear manufactured to IEC standards require that all parts of the main circuit where access is required or provided shall be grounded before becoming accessible. This typically requires the use of permanently installed grounding switches which meet the short time and momentary ratings of the switchgear. The circuit breaker might be used as a grounding device with a special accessory.	ANSI/IEEE has no similar requirements. However, when grounding is required, a separate ground and test device is commonly used. A new (first ever) standard is being written to cover these devices even though they have been used for many decades. G&T devices may have fault making and/or breaking capability, and may be designed to allow voltage tests to be performed on the switchgear.	

IEC	ANSI / IEEE	Comments
Voltage transformer fusing		
No requirements.	Requires primary and secondary fusing of VT's in metal-clad switchgear. Primary fuses must be disconnected from the primary circuit before they become accessible.	
Secondary devices and control wiring		
Requires isolation of control devices and control wiring from primary circuits by grounded metal barriers (except for short lengths of wire at terminals of devices like CT's).	= ditto =	IEC allows wiring to be segregated using insulating tubes, which ANSI does not.
No comparable information to ANSI but does cover contact ratings and operation in IEC 694 which ANSI does not.	Provides numerous details of control wiring including wire sizes, wire types, terminals, terminal blocks, designation of auxiliary contacts, device function numbers, voltage supply limits, polarities etc.	
IEC 298 covers operation of the mechanisms of the primary switching devices.	ANSI covers the same but in the circuit breaker standards themselves, not the switchgear standards.	
Nameplates		
Nameplates are required to be attached to the switchgear. IEC requires the number of the standard used.	Nameplates are required to be attached to the switchgear. ANSI/IEEE requires the manufacturers address.	Both require the manufacturers name, type designation and any other designation, and the appropriate ratings.
Internal barriers and safety shutters		
Requires internal barriers and shutters to be used. Grounded metallic barriers, and metallic or insulating shutters for removable elements (to protect against contact of the primary circuit when the element is removed). Where buses penetrate barriers, suitable bushings or other insulating materials shall be provided.	= ditto =	
There shall be separate compartments for each main switching device, components connected to one side of a main switching device, components connected to the other side of a main switching device. Where more than one set of busbars is provided, each shall be in a separate compartment.	ANSI/IEEE requires more extensive use of barriers. In addition to those listed to the left under IEC, there shall also be barriers between primary sections of adjacent vertical sections, including the main bus in each vertical section.	IEC does not require the use of barriers between vertical sections of main bus, so that very often the main bus compartment is one compartment for the entire length of the switchgear lineup.
No requirement.	Voltage transformers and control power transformers shall be in separate compartments. Only one compartment is required for a polyphase circuit.	
No requirement.	Required is a metal barrier in front of the circuit interrupting device to ensure that no primary circuit components are exposed when the device is in the connected position.	

IEC	ANSI / IEEE	Comments
Interlocks		
Required to prevent removable elements from being inserted or withdrawn unless the switching device is in the open condition and to prevent closing the switching device unless it is in the disconnected, test or connected position. The control circuit must be connected before the switching device can be closed in the connected position	= ditto =	
It shall not be possible for the contacts to move from the open position unless there is sufficient energy to permit proper closing to take place, including making the short circuit making current rating.	Circuit breakers equipped with stored energy mechanisms shall only allow the release of stored energy if the mechanism has been fully charged.	These two requirements while worded differently achieve the same basic goal.
No requirement.	Interlocks shall be provided to : 1) hold the removable element in place in the connected and test positions, and in the disconnected position if distinct from the test position. 2) to prevent disconnection and access to primary fuses on control power transformers unless the secondary circuit is open. 3) to protect operators or maintenance personnel from the effects of accidental discharge of stored energy. 4) locking means to prevent circuit breakers from being moved into the connected position.	
Interchangeability of removable elements		
All components of the same rating and construction which may need to be replaced to be interchangeable. Removable parts with different ratings that are interchangeable must withstand the rated insulation level of the fixed parts.	All removable switching devices of the same type and rating to be physically and electrically interchangeable. All elements not of the same type and rating shall not be interchangeable.	Under IEC, there is no restriction against interchangeability of parts of different ratings.
Enclosures		
Enclosures shall be metallic. No specific material thickness is required. No requirement for paint, paint finish or labeling.	Enclosures shall be metallic. ANSI/ IEEE specifies a certain minimum thickness in certain parts of the enclosures and interior barriers. ANSI specifies some requirements for the paint finish including a preferred paint colour. Some requirements for precautionary labeling is included.	
IEC specifies the degree of protection to be provided by the enclosure.	ANSI/IEEE does not specify the same way, but lists three categories of enclosures in Annex A.	
Discusses requirements for indoor enclosures in clause 5.102	Discusses requirements for indoor enclosures in clause 6.2.11, corresponding approximately to category B in Annex A.	

IEC	ANSI / IEEE	Comments
Discusses outdoor enclosures in clause 5.101.2b.	Discusses outdoor enclosures with and without an operating and maintenance aisle. Requirements for doors, door stops, heaters etc. are provided.	
General features		
Covers several aspects of liquid or gas filled compartments.	No requirements.	
No requirements.	Covers several aspects of operating accessories, circuit breaker wiring, position indicating lights etc.	
Application guidelines		
IEC 298 does not address application guidelines in any detail. There are recommendations for unusual service conditions, but usually to the extent that the switchgear shall be designed for the specified conditions and the manufacturer shall be consulted. Some basic rules about applying circuit breakers are included in section 8.	ANSI/IEEE include information on usual and unusual service conditions. Addressed are topics such as use at high altitudes, high ambient temperatures, severe environments (fumes, corrosive gases or dust, high humidity, vibration, tilting, shock, seismic environments), and operation at currents above the rated continuous current.	
Handling, storage and installation requirements		
IEC provides a detailed list of instructions that should be provided by the manufacturer to the user.	ANSI/IEEE provides actual detailed information on how to perform the necessary steps.	
Information to be provided with quotations and orders		
IEC provides detailed lists of information to be given with quotations and orders.	No recommendations. Typically in North America, each tender has fill-in sheets in the purchasers own format that are required to be filled out.	

Table 2
Comparison of voltage ratings

Rated Voltage (kV)		Impulse Withstand (kV BIL)		Power Frequency Withstand (kV)	
IEC	**ANSI**	**IEC**	**ANSI**	**IEC**	**ANSI**
3.6	--	40	--	10	--
--	4.76	--	60	--	19
7.2	8.25	60	95	20	36
12	--	75	--	28	--
17.5	15	95	95	38	36
24	27	125	125	50	60
36	38	170	150	70	80
52	--	250	--	95	--

Table 3
Comparison of allowable temperature rises

Component	IEC Standard		ANSI/IEEE Standard	
	Rise °C	Reference	Rise°C	Reference
Insulating materials				
IEC class Y ANSI class 90	50	IEC 694 table V	50	ANSI C37.20.2
IEC class A ANSI class 105	60		65	Table 3
IEC class E ANSI ------	80		---	
IEC class B ANSI class 130	90		90	
IEC class F ANSI class 155	115		115	
IEC class H ANSI class 180	140		140	
IEC class C ANSI class 220	(1)		180	
Bus and connections, in air				
Bare copper connections	50	IEC 694 table V	30	ANSI C37.20.2
Bare aluminum connections	50		(3)	Table 4
Bus with plated connections	(2)		65	
Silver/nickel plated bus conn's	75		65	
Tin plated bus connections	65		65	
Bare copper cable connections	50		30	
Plated cable terminals	65		45	
Contacts in air				
Bare copper contacts	35	IEC 694 table V		(4)
Silver/nickel plated contacts	65			
Tin plated bus contacts	50			
Air surrounding devices	(5)	IEC 298 Clause 4.4.2	(5)	ANSI C37.20.2 Clause 4.5.4
Air surrounding Insulated Cables		(6)	25	ANSI C37.20.2 Clause 4.5.5
External Parts				
Normally handled by operator	30 (7)	IEC 298 Clause 4.4.2	10	ANSI C37.20.2 Clause 4.5.6
Accessible but not handled	40		30	
Not accessible	(6)		70	

(1) Limited only by the requirement not to cause any damage to surrounding parts

(2) IEC places no limit on buses, only on contacts and connections

(3) Bare aluminum connections are specifically prohibited by ANSI/IEEE

(4) ANSI/IEEE does not differentiate between connections and contacts

(5) Must not cause devices to operate above their own temperature limits

(6) Not addressed in IEC standards

(7) Applies to enclosures & covers. Other parts not addressed by the standard