Appendix 3: IEC - ANSI comparison

IEC 56-1987 - ANSI C37-06 1987 COMPARISON

CONTENTS page

Appendix 3:
IEC - ANSI comparison
(cont'd)

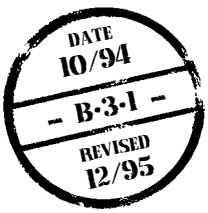
The following comparison is based on different circuit breaker characteristics.

Summary of main differences

theme	ANSI	IEC
asymmetric breaking capacity on terminal faults	50% with current derating	30% without derating
isolating level: impact wave	impose chopped waves for outdoor equipment 115% U_w/3 s 129% U_w/2 s	
allowable short time current peak value	2.7 I_{sc}	2.5 I_{sc}
Transient Recovery Voltage (1)	approximately 2 times stricter	
electrical endurance	4 times K.S.I_{sc}	3 fois I_{sc}
mechanical endurance	1 500 to 10 000 depending on U_a and I_{sc}	2 000
motor overvoltages	no text	type test circuit

(1) The ANSI peak voltage is 10% higher than the voltage defined by the IEC. The E_2/t_2 gradient is 50% steeper than the U_c/t_3 gradient.

On the other hand, the steepest part of the curve is the initial part, where the SF6 is reconstituted. The two standards easily allow SF6 to be reconstituted.



Appendix 3:
IEC - ANSI comparison
(cont'd)

1 - RATED VOLTAGE U_n (kV)

According to IEC

Standardized values for U_n (kV) : 3.6 - 7.2 - 12 - 17.5 - 24 - 36 kV

According to ANSI

The ANSI standard defines a grade and a "voltage range factor K" which defines a rated voltage range **with constant power.**

$$K = \frac{U_{max.}}{U_{min.}}$$

Standardized values for U_n (kV)

Indoor equipment

grade (kV)	**$U_{max.}$** (kV)	**$U_{min.}$** (kV)	**K**
4.16	4.76	3.85	1.24
7.2	8.25	6.6	1.25
13.8	15	11.5	1.3
38	38	23	1.65

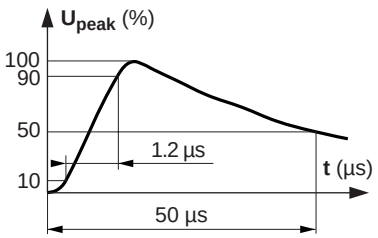
Outdoor equipment

grade (kV)	**K**
15.5	1
25	1
38	1

2 - RATED ISOLATING LEVEL

According to IEC

rated voltage (kV)	**impact wave withstand (BIL)** (kV)	**industrial frequency withstand** (kV rms)
7.2	60	20
12	75	28
17.5	95	38
24	125	50
36	170	70



standardized wave 1.2/50 µs

According to ANSI

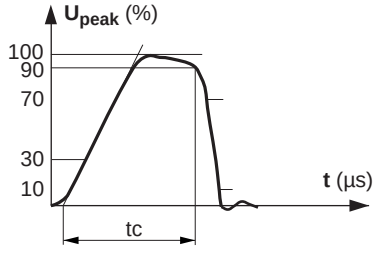
Indoor equipment

grade (kV)	**impact wave withstand (BIL)** (kV)	**industrial frequency withstand** (kV rms)
4.16	60	19
7.2	95	36
13.8	95	36
38	150	80

Outdoor equipment

grade (kV)	**impact wave withstand (BIL)** (kV)	**industrial frequency withstand** (kV rms)
15.5	110	50
25.8	125 150	60
38	150 200	80

BIL : Basic Insulation Level
Outdoor equipment is tested with chopped waves.
The impact wave withstand is equal to:
1.29 BIL for a time tc = 2 µs
1.15 BIL for a time tc = 3 µs



chopped wave according to ANSI for outdoor equipment

Appendix 3:
IEC - ANSI comparison
(cont'd)

3 - RATED VOLTAGE DURING NORMAL RUNNING

According to IEC

Rated current values: 400 - 630 - 1250 - 1600 - 2500 - 3150 A

According to ANSI

Rated current values: 1200 - 2000 - 3000 A

4 - ALLOWABLE SHORT TIME CURRENT

According to IEC

Rated short-circuit breaking capacity values (kA):
6.3 - 8 - 10 - 12.5 - 16 - 20 - 25 - 31.5 - 40 - 50 - 63 kA

According to ANSI

Rated short-circuit breaking capacity values (kA):

Outdoor equipment: 12.5 - 20 - 25 - 31.5 - 40

Indoor equipment

grade	**breaking capacity**	
(MVA)	I at $U_{max.}$ (kA)	KI at $U_{min.}$ (kA)
250	29	36
350	41	49
500	18	23
750	28	36
1000	37	48
1500	21	35
2750	40	40

5 - ALLOWABLE CURRENT PEAK VALUE AND MAKING CAPACITY

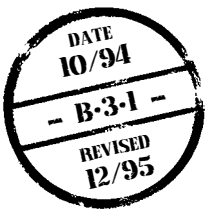
According to IEC

The allowable short time current peak value is equal to 2.5 I_{sc}.

According to ANSI

The allowable short time current peak value is equal to 2.7 K I_{sc} peak value;
1.6 K I_{sc} root mean square value.

K: voltage factor.



Appendix 3:
IEC - ANSI comparison
(cont'd)

6 - RATED SHORT-CIRCUIT TIME

According to IEC

The rated short-circuit time is equal to 1 or 3 seconds.

According to ANSI

The rated short-circuit time is equal to 3 seconds.

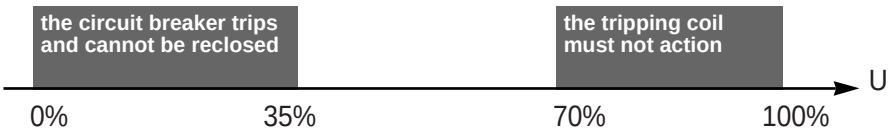
7 - RATED VOLTAGE SUPPLYING OPENING AND CLOSING DEVICES AND AUXILIARY CIRCUITS

According to IEC

Auxiliary circuit supply voltage values:
- in direct current (dc): 24 - 48 - 60 - 110 or 125 - 220 or 250 volts.
- in alternating current (ac): 120 - 220 - 230 - 240 volts.

The operating voltages must be within the following ranges:
- motor and closing trips: -15% to +10% of U_n in dc and ac
- opening trips:

-15% to +10% of U_n in ca; -30% to +10% of U_n in dc
- minimum voltage opening trips.



According to ANSI

Auxiliary circuit supply voltage values:
- in direct current (dc): 24 - 48 - 125 - 250 volts.
- in alternating current (ac): 120 - 240 volts.

The operating voltages must be within the following ranges:

Motor and closing trips

voltage	voltage range
48 Vdc	36 V to 56 V
125 Vdc	90 V to 140 V
250 Vdc	180 V to 280 V
120 Vac	104 V to 127 V
240 Vac	208 V to 254 V

Opening trips

voltage	voltage range
24 Vdc	14 V to 28 V
48 Vdc	28 V to 56 V
125 Vdc	70 V to 140 V
250 Vdc	140 V to 280 V
120 Vac	104 V to 127 V
240 Vac	208 V to 254 V

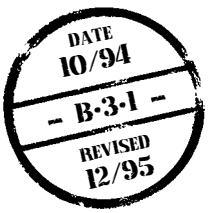
8 - RATED FREQUENCY

According to IEC

Rated frequency: 50 Hz.

According to ANSI

Rated frequency: 60 Hz.



Appendix 3:
IEC - ANSI comparison
(cont'd)

9 - RATED OPERATING CYCLE SHORT-CIRCUIT BREAKING CAPACITY

ANSI specifies 50% asymmetry and the IEC 30%. In 95% of applications, 30% is sufficient. When 30% is too low, this means that the applications have specific requirements (nearby generators) for which the asymmetry may be higher than 50%. For the two systems of standards, the designer must check the circuit breaker breaking capacity.
The difference is not important since even if the asymmetry factor "S" is not taken into account, it remains equal to 10%.

$$\text{ANSI: } I_{asym.} = I_{sym.}\sqrt{1 + 2\,A^2} = 1.22\ I_{sym.}(A = 50\%)$$

$$\text{IEC: } I_{asym.} = I_{sym.}\sqrt{1 + 2\,A^2} = 1.08\ I_{sym.}(A = 30\%)$$

According to IEC

The short-circuit breaking tests must satisfy the following 5 test cycles (cf. § 5 - 10)

cycle no.	% $I_{sym.}$	% aperiodic component
1	10	≤ 20
2	20	≤ 20
3	60	≤ 20
4	100	≤ 20
5*	100	30

**for circuit breakers opening in less than 80 ms*

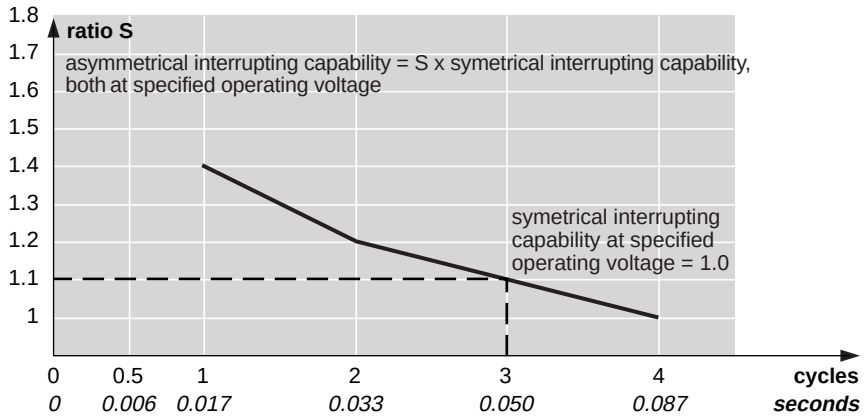
According to ANSI

The circuit breaker must be able to break:
■ the rated short-circuit current at the rated maximum operating voltage,
■ K times the short-circuit current (maxi symetrical interrupting capability with K: voltage range factor) at the rated maximum operating voltage (maxi voltage/K),
■ between two currents obtained through the relation:

$$\frac{\text{maxi symetrical current}}{\text{rated short-circuit current}} = \frac{\text{rated maxi voltage}}{\text{rated voltage}} = K$$

A constant breaking power is thus obtained (in MVA) over a given voltage range. Furthermore, the asymmetrical current will depend on the following table when S = 1.1 for MG circuit breakers.

circuit breaker contact parting time
sum of 1/2 cycle tripping delay plus the opening time of the individual breaker



Appendix 3:
IEC - ANSI comparison
(cont'd)

Rated short-circuit breaking capacity values (kA): cf. § 4

cycle no.	broken current	% aperiodic component
1	10	50 - 100
2	30	< 20
3	60	50 - 100
4	100	< 20
5	KI to V/K	< 20
6	SI to V	50 - 100
7	KSI to V/K	50 - 100
8	electrical endurance	
9/10	reclosing cycle at RSI and RKSI	
11	C - 2 s - O to KI	
12	rated I_{sc} time I_{sc} = KI during 3 s	
13/14	single-phase tests at KI and at KSI (0.58 V)	

The short-circuit breaking tests must satisfy the following 14 test cycles where:
I: symmetrical breaking capacity at maxi. voltage
R: Reclosing factor

K: voltage range factor = $K = \frac{V_{max.}}{V_{min.}}$

S = asymmetrical factor = $\frac{I_{asym.}}{I_{sym.}}$ = 1.1 for MG circuit breakers

V: rated maximum voltage

Example : I_{sc} = 40 kA
asymmetry % = 50%
$I_{asym.}$ = 1.1 x 40 = 44 kA

$$I_{sym.} = \frac{44}{\sqrt{1 + 2\,(50\%)^2}} = \frac{44}{1.22} = 36 \text{ kA}$$

Cycle 6 will thus be tested at 36 kA + 50% asymmetry giving 44 kA of total current.

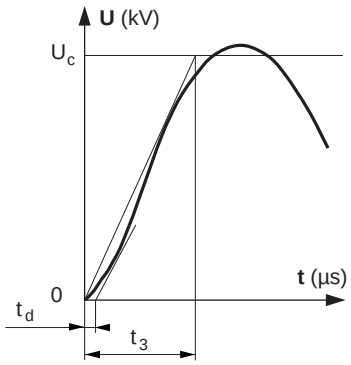
DATE 10/94 - B·3·1 - REVISED 12/95

Appendix 3:
IEC - ANSI comparison
(cont'd)

10 - ASSOCIATED TRANSIENT RECOVERY VOLTAGE (TRV) (cf. § 5.11)

The ANSI peak voltage is 10% higher than the voltage defined by the IEC, the E_2/t_2 gradient is 50% steeper than the U_c/t_3. On the other hand, the steepest part of the curve is the initial part, where the SF6 is reconstituted. The two standards easily allow SF6 to be reconstituted.
The ANSI t_2 values are valid for outdoor type circuit breakers. Other t_2 values for indoor type circuit breakers are being worked on, and these values are much closer to the IEC values.

According to IEC



Representation of a specified TRV by a reference plotting with 2 parameters and by right-hand segment defining a delay.

t_d: delay time
t_3: time taken to reach U_c
U_c: TRV peak voltage in kV

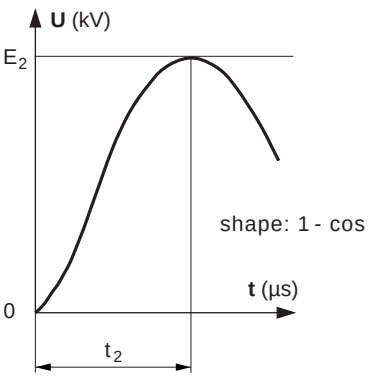
☞ **note:** *the TRV depends on the asymmetry. It is given for an asymmetry of 0%.*

Rated TRV value

rated voltage (U_n in kV)	**TRV value** (U_c in kV)	**time** (t_3 in µs)	**delay** (t_d in µs)	**stepping up speed** (U_c/t_d in kV/µs)
7.2	12.3	52	8	0.24
12	20.6	60	9	0.34
17.5	30	72	11	0.42
24	41	88	13	0.47
36	62	108	16	0.57

$$U_c = 1.4 \cdot 1.5 \cdot \frac{\sqrt{2}}{\sqrt{3}} \cdot U \qquad t_d = 0.15\ t_3$$

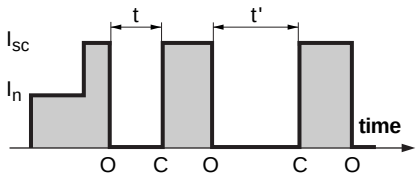
According to ANSI



E_2: TRV peak voltage
$E_{2\ peak}$ = 1.88 max. rated U
$E_{2\ rms}$ = 1.5 max. phase - earth U
t_2 = 36 ms for 15.5 kV
= 52 ms for 25.8 kV
= 63 ms for 38 kV
TRV = E_2/t_2 x 1.14

Appendix 3:
IEC - ANSI comparison
(cont'd)

rated operating cycle according to IEC: O - t - CO - t' - CO



O represents an opening operation.
CO represents a closing operation immediately followed by an opening operation.

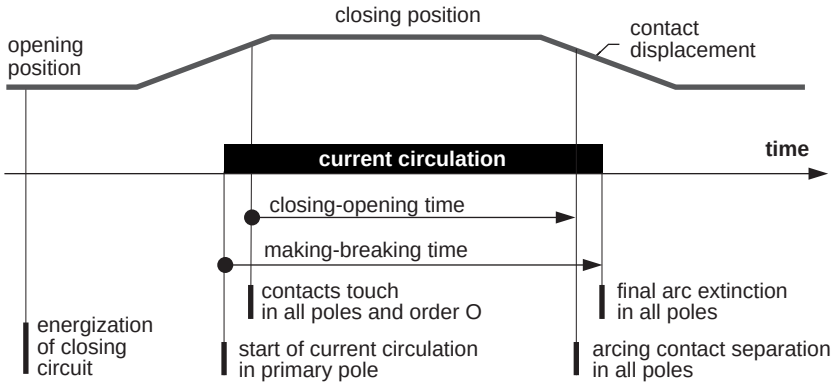
11 - RATED OPERATING CYCLE

According to IEC

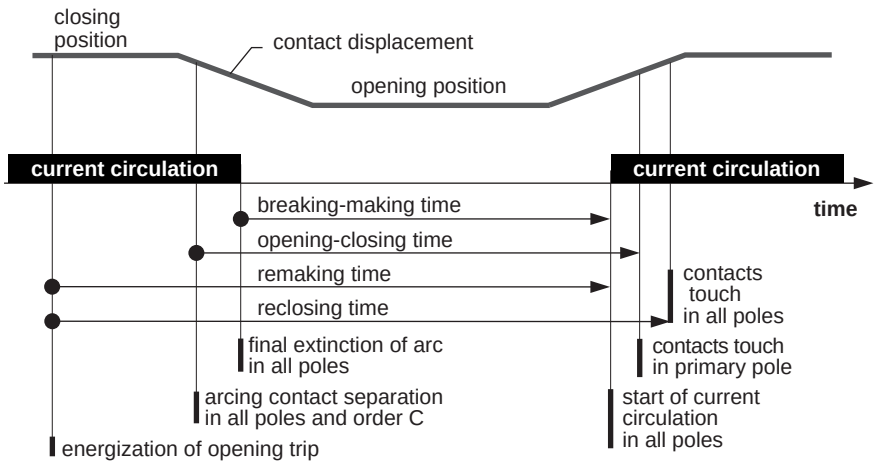
There are three rated operating cycles:
slow: O - 3 mn - CO - 3 mn - CO
fast 1: O - 0,3 s - CO - 3 mn - CO
fast 2: O - 0.15 s - CO - 15 s - CO.

☞ **note:** *other cycles may be required.*

Closing-opening cycle

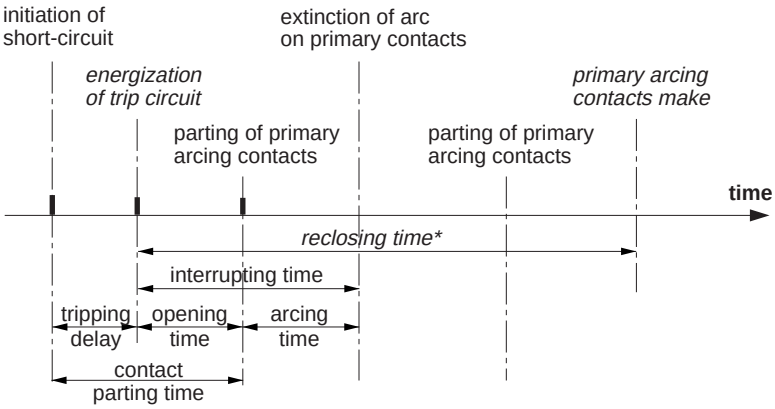


Automatic reclosing cycle



According to ANSI

Only one rated operating cycle: **CO - 15 s - CO**



* reclosing time is the time interval between energization of the trip circuit and making of the primary arcing contacts.

Appendix 3:
IEC - ANSI comparison
(cont'd)

12 - RATED UNBALANCE PHASE BREAKING CAPACITY

According to IEC (cf. § 5 - 12)

In practice, the circuit breaker is required to break **a current equal to 25% of the fault current at the terminals,** under a voltage equal to double of the voltage in relation to the earth.

The industrial frequency recovery voltage (TRV) is equal to:

- $2.0\sqrt{3}\ U_n$ for networks where the neutral is direct to the earth.
- $2.5\sqrt{3}\ U_n$ for other networks.

U_n is equal to the rated circuit breaker voltage.

Peak TRV values for networks where the neutral is not earthed:

$$U_c = 1.25 \cdot 2.5 \cdot \frac{\sqrt{3}}{\sqrt{2}} \cdot U_n$$

rated voltage (U_n in kV)	**TRV value** (U_c in kV)	**time** (t_3 in µs)	**stepping up speed** (U_c/t_d (kV/ µs)
7.2	18.4	104	0.18
12	30.6	120	0.26
17.5	45	144	0.31
24	61	176	0.35
36	92	216	0.43

According to ANSI

In practice, the circuit breaker is required to break **a current equal to 25% of the fault current at the terminals,** under a voltage equal to the voltage in relation to the earth.

Appendix 3: IEC - ANSI comparison (cont'd)

13 - RATED OFF-LOAD CABLE BREAKING CAPACITY (cf. § 5 - 13)

According to IEC

The rated off-load cable breaking capacity specification for a circuit breaker is not obligatory and is considered as unnecessary for voltages ≤ to 24 kV.

Normal rated off-load cable breaking capacity values

rated voltage U (kV)	**rated off-load cable breaking capacity** I_c (A rms)
7.2	10
12	25
17.5	31.5
24	31.5
36	50

Allowable maximum overvoltages

rated voltage U (kV)	**overvoltage** pu (kV) = $U_n \frac{\sqrt{2}}{\sqrt{3}}$
7.2	4.5
12	4
17.5	4
24	3.8
36	3.8

According to ANSI

Cf. unique battery breaking.

14 - RATED OFF-LOAD LINE BREAKING CAPACITY

According to IEC

The rated off-load line breaking capacity specification is limited to circuit breakers for operating three-phase overhead lines with a rated voltage ≥ 72 kV.

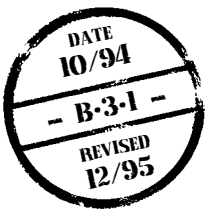
According to ANSI

Indoor equipment

max. rated voltage (kV)	**rated off-load line breaking capacity** (A rms)
4.76	1
8.25	1
15	2
38	5

Outdoor equipment

max. rated voltage (kV)	**rated off-load line breaking capacity** (A rms)
15.5	100
25.8	100
38	100



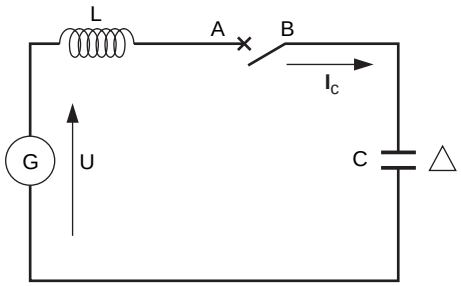
Appendix 3:
IEC - ANSI comparison
(cont'd)

15 - UNIQUE CAPACITOR BANK BREAKING CAPACITY

According to IEC

The capacitor breaking capacity specification is not obligatory. The capacitor breaking capacity is equal to 0.7 times the value of the device's rated current.

rated current (A)	**capacitor breaking capacity** (A)
400	280
630	440
1250	875
2500	1750
3150	2200



The maximum overvoltage value allowable is equal to 2.5 pu, in other words:

$2.5 \times U_n \frac{\sqrt{2}}{\sqrt{3}}$ with pu = $U_n \frac{\sqrt{2}}{\sqrt{3}}$

According to ANSI

The capacitor breaking capacity is:

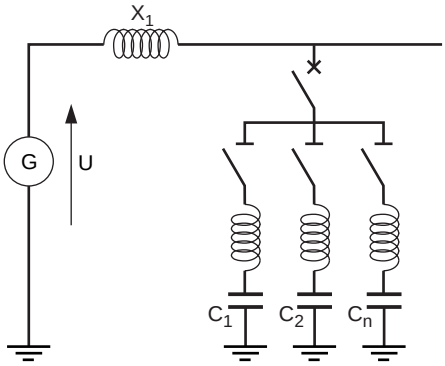
For indoor equipment

rated voltage $U_{max.}$ (kV)	**short-circuit breaking capacity** (kA)	**rated current** (A)	**capacitor breaking capacity** (A)
4.76	29	1200	630
	29	2000	1000
	41	1200/2000	630
	41	3000	1000
8.25	33	1200	630
	33	1200	1000
15	18	1200	630
	18	2000	1000
	28	1200	630
	28	2000	1000
	37	1200	630
	37	2000	1000
	37	3000	1600
38	21	1200/2000/3000	250
	40	1200/3000	250

For outdoor equipment

rated voltage $U_{max.}$ (kV)	**capacitor breaking capacity** (A)
15.5	400
25.8	400
38	250

Appendix 3:
IEC - ANSI comparison
(cont'd)



16 - RATED STAGE CAPACITOR BANK BREAKING CAPACITY

According to IEC

The rated stage capacitor bank breaking capacity specification is not obligatory.

According to ANSI

Cf. unique capacitor bank § 15.

17 - RATED CAPACITOR BANK MAKING CAPACITY

The rated capacitor bank making capacity is the peak value of the current which the circuit breaker must be able to make under its rated voltage and with an inrush current frequency appropriate to the operating conditions.

According to IEC

The rated capacitor bank making capacity values must be higher than the make current value (see capacitor application).
When operating, the inrush current frequency is normally in the 2 - 5 kHz zone.

According to ANSI

The ANSI standard fixes the inrush current value and frequency (back to back capacitors).

For indoor equipment

voltage	**current**	**inrush current**	
$U_{max.}$ (kV)	(A)	I_{peak} (kA)	frequency (kHz)
4.76	600	15	2
	1000	15	1.27
8.25	600	15	2
	1000	15	1.27
15	600	15	2
	1000	15	1.27
	1600	25	1.33
38	250	18	6
	250	25	8.48

For outdoor equipment

voltage	**current**	**inrush current**	
$U_{max.}$ (kV)	(A)	I_{peak} (kA)	frequency (kHz)
15.5	400	20	4.24
25.8	400	20	4.24
38	250	20	4.24

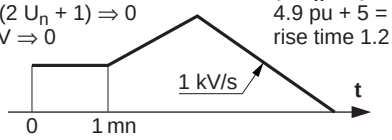
Appendix 3:
IEC - ANSI comparison
(cont'd)

18 - RATED LOW INDUCTIVE CURRENT BREAKING CAPACITY (cf. § 5 - 18)

According to IEC (cf. § 4.112 - IEC 56 - 87)
This subject is being studied.

Motor isolating levels
The IEC 34 stipulates motor isolating levels.
The industrial frequency and impact withstand tests are given in the table below (table 1: inductive current breaking, chapter 3, part B, CIGRE).

rated isolating levels for rotating equipment

isolation	test at 50 (60) Hz rms	impact test BIL
between turns		**($4\ U_n + 5$) kV** 4.9 pu + 5 = 31 kV to 6.6 kV (50% on a sample) rise time 0.5 µs
in relation to the earth	**($2\ U_n + 1$) kV** $2\ U_n + 1 \Rightarrow 2\ (2\ U_n + 1) \Rightarrow 0$ 14 kV ⇒ 28 kV ⇒ 0 	**($4\ U_n + 5$) kV** 4.9 pu + 5 = 31 kV to 6.6 kV rise time 1.2 µs

According to ANSI
Non standard.

Appendix 3: IEC - ANSI comparison (cont'd)

19 - NORMAL OPERATING CONDITIONS

The equipment is designed to operate normally in the following conditions:

A) TEMPERATURE

According to IEC

0 °C immediate ambient temperature	**installation** indoor	outdoor
minimum	-5 °C	-25 °C
maximum	+40 °C	+40 °C
daily average maximum value	35 °C	35 °C

Derating should be provided for all equipment operating in different conditions from those described above (see derating chapter).

According to ANSI

0 °C immediate ambient temperature	**installation**
minimum	-30 °C
maximum	+40 °C

B) ALTITUDE

According to IEC

The altitude must not be higher than 1000 metres, if higher derating is necessary.

According to ANSI

The altitude must not be higher than 3300 feet (1000 metres), if higher derating is necessary.

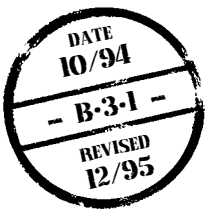
C) HUMIDITY

According to IEC

average relative humidity value time period	indoor equipment
24 hours	95%
1 month	90%

According to ANSI

No specific constraints.



Appendix 3:
IEC - ANSI comparison
(cont'd)

20 - ELECTRICAL ENDURANCE

MG circuit breakers ensure 15 times I_{sc} minimum. The IEC and ANSI standards impose values which are far too low since they take account oil breaking circuit breakers.

These values are not important and if so required by the customer, the value of the considered device should be supplied.

According to IEC

The electrical endurance is equal to 3 times I_{sc}.

According to ANSI

The electrical endurance is equal to 4 times K.S.I_{sc}
I_{sc}: symmetrical breaking capacity at maxi voltage
S: asymmetry factor
K: voltage range factor

21 - MECHANICAL ENDURANCE

According to IEC

The mechanical endurance is 2 000 operating cycles.

According to ANSI

The mechanical endurance is between 1 500 and 10 000 operating cycles depending on the voltage and breaking capacity.

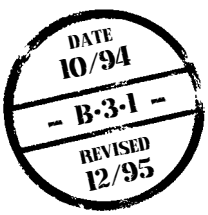
22 - CONSTRUCTION

According to IEC

The IEC does not impose any particular constraints. The manufacturer is however responsible for determining what kind of material is needed (thickness, etc.) in order to ensure a solid performance.

According to ANSI

The ANSI imposes a thickness of 3 mm for sheet metals.



Appendix 3:
IEC - ANSI comparison
(cont'd)

23 - DERATING

According to IEC

Refer to paragraph 6 of technical guide.

According to ANSI

The ANSI C37 04 standard provides for temperatures higher than 1 000 metres:
■ a correction factor for the voltage applicable on the rated isolating level and on the rated maximum voltage.
■ a correction factor for the rated current during normal running.
The correction factor table depending on the altitude
(Altitude Correction Factors : ACF)

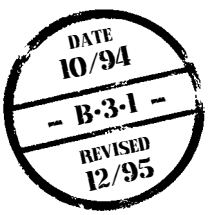
altitude		**ACF for voltage**	**ACF for continous current**
(ft)	(m)		
3 300	1 000	1.00	1.00
5 000	1 500	0.95	0.99
10 000	3 000	0.8	0.96

☞ **note:** *for "sealed system" type circuit breakers, it is not necessary to apply the ACF voltage on the rated maximum voltage.*

24 - COORDINATION OF RATED VALUES

According to IEC

rated voltage	**rated short-circuit breaking capacity**	**rated current during normal running**					
U (kV)	I_{sc} (kA)	I_n (A)					
3.6	10	400					
	16		630	1250			
	25			1250	1600	2500	
	40			1250	1600	2500	3150
7.2	8	400					
	12.5	400	630	1250			
	16		630	1250	1600		
	25		630	1250	1600	2500	
	40			1250	1600	2500	3150
12	8	400					
	12.5	400	630	1250			
	16		630	1250	1600		
	25		630	1250	1600	2500	
	40			1250	1600	2500	3150
	50			1250	1600	2500	3150
17.5	8	400	630	1250			
	12.5		630	1250			
	16		630	1250			
	25			1250			
	40			1250	1600	2500	3150
24	8	400	630	1250			
	12.5		630	1250			
	16		630	1250			
	25			1250	1600	2500	
	40			1250	1600	2500	3150
36	8		630				
	12.5		630	1250			
	16		630	1250	1600		
	25			1250	1600	2500	
	40			1250	1600	2500	3150



Appendix 3:
IEC - ANSI comparison
(cont'd)

According to ANSI

rated maximum voltage	**short-circuit breaking capacity at $U_{max.}$**	**rated minimum voltage**	**short-circuit breaking capacity at $U_{min.}$**	**rated current during normal running**				
$U_{max.}$ (kV)	I_{sc} (kA)	(kV)	I_{sc} (kA)	I_n (A)				
4.76	18	3.5	24		1200			
	29	3.85	36		1200	2000		
	41	4	49		1200		3000	
8.25	7	2.3	25	600	1200	2000		
	17	4.6	30		1200			
	33	6.6	41		1200	2000		
15	9.3	6.6	21		1200			
	9.8	4	37		1200			
	18	11.5	23		1200	2000		
	19	6.6	43		1200	2000		
	28	11.5	36		1200	2000		
	37	11.5	48		1200		3000	
15.5	8.9	5.8	24	600				
	18	12	23		1200			
	35	12	45		1200			
	56	12	73			2000	3000	4000
25.8	5.4	12	12	600				
	11	12	24		1200			
38	22	23	36		1200		3000	
	36	24	57		1200