Tests and Testing Procedures According to IEC/EN Standards

Products such as connecting devices, rail-mounted terminal blocks and connectors, etc., have there own product-specific test specifications. The following paragraphs which include the most important tests are both limited to describing the test methods and explaining the test purpose. The values stated in the following paragraphs (e.g. voltages, temperatures, forces, etc.) are solely for the purpose of clarification and may vary according to the test used.

Mechanical Tests

All WAGO products meet the requirements of the following mechanical tests.

• Connecting conditions

Conductor connection
Two connection systems have proven themselves in the market for spring clamp connectors:

The **Push-wire connection** in applications with exclusively solid conductors; e.g. for lighting and building wiring, telecommunication, house communication or alarm systems.
Conductor cross section range
0.28 mm² up to 4 mm²/
AWG 24 – AWG 12.

The **CAGE CLAMP® connection** as a **universal clamping system** for solid, stranded and fine-stranded conductors for applications in industrial electrical and electronic engineering; preferentially for fine-stranded conductors in the elevator industry, in power stations, the chemical, automobile industry and on board ships.
Conductor cross section range
0.08 mm² up to 35 mm²/
AWG 28 – AWG 2.

The **CAGE CLAMP®S** is a further development of the universal CAGE CLAMP® allowing the connection of solid, stranded and fine-stranded conductors rated AWG 24 (0.2 mm²) to AWG 6 (16 mm²) (AWG 4/25 mm² only "f-st") and offering all the benefits and safety of the original CAGE CLAMP® connection. Furthermore, using the CAGE CLAMP®S connection technology, solid and stranded conductors rated AWG 20-6 (0.5 mm² - 16 mm²) as well as fine-stranded conductors with crimped ferrule rated from AWG 20 (0.5 mm²) to AWG 6 (16 mm²) can be connected by simply pushing them in.

The conductor entry hole is designed to ensure an optimum adaptation to the insulation cross sections of conductor rated cross sections, thus guaranteeing good conductor guidance.

This is of particular importance for applications subject to vibration.

In practice, there is always a danger of very small cross section of fine-stranded wire being fragile enough to allow it to be pushed into the point where the conductor insulation is being clamped by the clamping unit.

In order to prevent resulting "accidental contact" we provide insulation stop sleeves for WAGO rail-mounted terminal blocks with cross section up to AWG 12 (4 mm²) which avoid this danger even with conductors of AWG 28 (0.08 mm²).

Rated cross section and connectable conductors
I. According to IEC 60999-1 / EN 60999-1 / VDE 0609 part 1, table 1:

Rated cross-section	Theoretical diameter of the largest conductor							Connectable conductors	
	Metric			AWG/Kcmil					
	Rigid		Flexible	Rigid			Flexible	Rigid	Flexible
	Solid	Stranded			Solid [b]	Class B Stranded [b]	Class I, K, M Stranded [c]		
mm²	mm	mm	mm	Wire size	mm	mm	mm		
0.2	0.51	0.53	0.61	24	0.54	0.61	0.64	To be specified in the relevant product standard	
0.34	0.63	0.66	0.8	22	0.68	0.71	0.80		
0.5	0.9	1.1	1.1	20	0.85	0.97	1.02		
0.75	1.0	1.2	1.3	18	1.07	1.23	1.28		
1.0	1.2	1.4	1.5	–	–	–	–		
1.5	1.5	1.7	1.8	16	1.35	1.55	1.60		
2.5	1.9	2.2	2.3[a]	14	1.71	1.95	2.08		
4.0	2.4	2.7	2.9[a]	12	2.15	2.45	2.70		
6.0	2.9	3.3	3.9[a]	10	2.72	3.09	3.36		
10.0	3.7	4.2	5.1	8	3.34	3.89	4.32		
16.0	4.6	5.3	6.3	6	4.32	4.91	5.73		
25.0	–	6.6	7.8	4	5.45	6.18	7.26		
35.0	–	7.9	9.2	2	6.87	7.78	9.02		

NOTE: Diameters of the largest rigid and flexible conductors are based on Table 1 of IEC 60228 A und IEC 60344 and, for AWG conductors, on ASTM B172-71 [4], IECA Publication S-19-81 [5], IECA Publication S-66-524 [6] and IECA Publication S-66-516 [7].
[a] Dimensions for class 5 flexible conductors only, according to IEC 60228 A.
[b] Nominal cross section + 5 %
[c] Largest diameter for conductors of classes I, K, M + 5 %

In practical use the conductor cross sections are approx. 5 % below the values stated in the table!

This specification concerning clamping units - IEC 60999-1/EN 60999-1/ VDE 0609 part 1, contains the following requirement (paragraph 7.1):

Clamping units must be suitable for connecting unprepared conductors.

With normal operating conditions this direct clamping, i. e. the direct contacting of the conductor at the current bar of the terminal block, results in optimum contact quality as any additional risk factors arising in connection with anti-splaying methods, are prevented.

Occasionally, due to wire handling on site, conductor anti-splaying methods may be necessary. Various methods may be used (as illustrated below).

For applications in special areas with extremely corrosive atmospheres, special conditions apply.

In this case the use of solid copper wires or fine-stranded copper wires with properly crimped, tinned copper ferrules or copper pin terminals is recommended.

Thus the fine strands are crimped to a dense inner core, like solid copper wire. This action prevents the ingress of the aggressive atmosphere (depending on the ppm concentration), which can diffuse into the conductor bundle along the individual strands and hence cause corrosion deposits between individual strands and the clamping point.

1 conductor per clamping unit

A number of VDE-specifications specify that only one conductor may be connected to each clamping unit, for example DIN VDE 0611, part 4/2.91, clause 3.1.9

The same applies to the recommendations of the association of the German automotive industry "Supply specification for the electrical equipment of machines, mechanical installations and buildings in the automotive industry" acc. to clause 15.1.1.3, draft 8.93.

Other VDE-specifications recommend the connection of one conductor per clamping unit unless the clamping unit is specifically tested and approved for the connection of several conductors:

VDE 0660, part 500, 08.00/
EN 60439-1: 1999, clause 7.8.3.7

VDE 0113, part 1, 11.98
EN 60 204-1: 1997, clause 14.1.1

VDE 0609, part 1, 12.00/
EN 60999-1:2000, clause 7.1

One conductor per clamping unit is therefore recommended, to meet the safety requirements of these relevant specifications.

This WAGO principle is the basis for a number of other technical and economic advantages:

Each conductor may be installed or removed without affecting previously installed wires.

Each conductor is clamped independently of the other. Any combinations of conductor cross section or kind of conductor (stranded and solid) can be connected.

Multi-conductor 3- and 4-wire terminal blocks may be selected, or a variety of commoning jumpers may be chosen.

II. According to IEC 60999-2, table 1:

Rated cross section	Theoretical diameter of the largest conductor					Connectable conductors	
	Metric		AWG/kcmil				
	Rigid stranded	fexible[a]	Gage	Rigid stranded	Flexible		
mm^2	mm	mm		mm	mm	Rigid	Flexible
50	9.1	11.0	0	9.64	12.08	To be specified in the relevant product standard	
70	11.0	13.1	00	11.17	13.54		
95	12.9	15.1	000	12.54	15.33		
–	–	–	0000	14.08	17.22		
120	14.5	17.0	250	15.34	19.01		
150	16.2	19.0	300	16.80	20.48		
185	18.0	21.0	350	18.16	22.05		
–	–	–	400	19.42	24.05		
240	20.6	24.0	500	21.68	26.57		
300	23.1	27.0	600	23.82	30.03		

a) Dimensions for class 5 flexible conductors only, according to IEC 60228A.

NOTE: Diameters of the largest rigid and flexible conductors are based on Table 1 and Table 3 of IEC 60228 A and, for AWG conductors, on ASTM B 172-71 [1], IECA Publication S-19-81 [2], IECA Publication S-66-524 [3] and IECA Publication S-66-516 [7].


Partial stripping of the insulation


Tinning of the end of the conductors


Tip-bonding of conductor ends


The use of crimped ferrules (gastight crimped)

With all anti-splaying methods which increase the diameter of the conductor, it is necessary to use the terminal block one size larger than the nominal cross section.


or pin terminals (gastight crimped), preferably produced from copper with tinned surface.

Tests and Testing Procedures According to IEC/EN Standards (continued)
Mechanical Tests (continued)

• Pull-out test according to IEC/EN 60947-7-1, IEC/EN 60998-2-2, IEC/EN 60999-1

This test simulates the mechanical stress on the clamping unit when, for example, the installer is pushing the conductor aside so that the adjacent clamping unit can be better operated or when he wants to check if the wire is connected properly by briefly pulling on it.
During the test, a pulling force is applied without jerks, for one minute, to the connected conductor. The pulling force is selected according to the cross-sectional area. The larger the cross-section of the conductor, the higher the pull-out force is selected. For example, the pulling force is 40 N for a conductor having a cross-section of 1.5 mm^2 (AWG 16) and 100 N for a conductor having a cross-section of 16 mm^2 (AWG 6). The values specified by the standard are the same for both screw-clamp and spring-clamp terminal blocks. During the test, the conductor shall neither slip out of the clamping unit nor break near the clamping unit.

Conductor pull-out forces

The clamping units of screwless terminal blocks have to withstand the pull-out forces as follows:

IEC 60947-1/EN 60947-1/VDE 0660, part 100, table 5
Low-voltage switchgear and controlgear, general rules

IEC 60947-7-1/EN 60947-7-1/ VDE 0611, part 1,
rail-mounted terminal blocks for copper conductors

IEC 60998-2-1/EN 60998-2-1/ VDE 0613, part 2-1, table 104
IEC 60998-2-2/ EN 60998-2-2/VDE 0613, part 2-2, table 103
Connecting devices for low-voltage circuits for household and similar purposes.

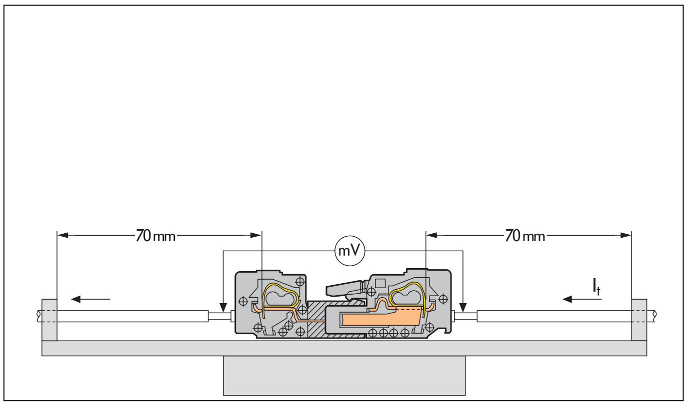
Particular requirements for connecting devices as separate entities with screw-clamp or with screwless terminal blocks.

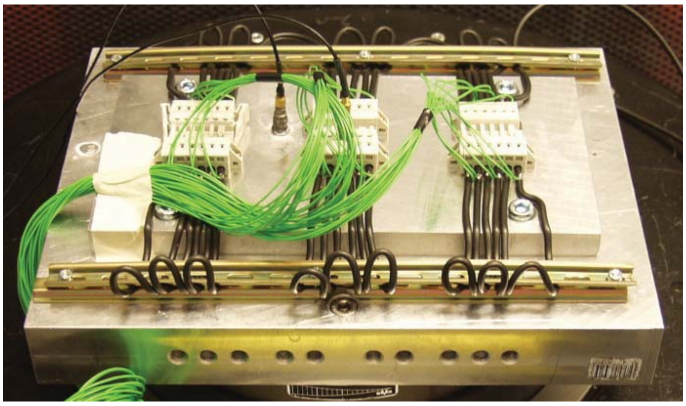
IEC 60999-1/EN 60999-1/VDE 0609, part 1, table 3:
IEC 60999-2/EN 60999-2, table 2:
Safety requirements for screw-clamp and screwless clamping units for electrical copper conductors

Rated cross-sectional area		Pull-out forces according to IEC/EN		
mm^2	AWG/MCM	60947-7-1 N	60998-2-2 N	60999-1/ -2 N
0.2 0.34	24 22	10 15	10 15	10 15
0.5 0.75	20 18	20 30	20 30	20 30
1.0 1.5	– 16	35 40	35 40	35 40
2.5 4.0	14 12	50 60	50 60	50 60
6.0 10	10 8	80 90	80 90	80 90
16 25	6 4	100 135	100 135	100 135
– 35	3 2	156 190	190	190
– 50	1 0	236 236		236
70 95	00 000	285 351		285 351
– 120	0000 250	427 427		427 427
150 185	300 350	427 503		427 503
– 240	400 500	503 578		503 578
300	600	578		578

• Shock test according to IEC/EN 60068-2-27, 60068-2-30; Railway applications IEC/EN 61373

The shock test is very similar to the vibration test (see pages 12.26 and 12.27) except that, instead of continuous vibrations, single shocks are applied to the specimen. Shock tests are usually carried out with an acceleration of 20 g over 11 milliseconds. Tests for special requirements often need much higher values. Just like vibration tests, shock tests are primarily used to test the voltage drop variation or contact breaks, etc.



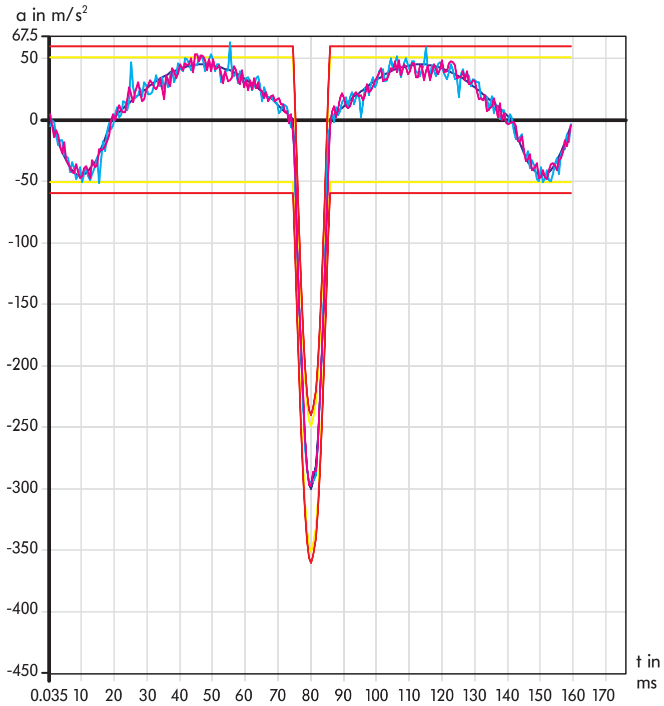


e.g. shock requirement
according to IEC/EN 60068-2-27

Half-sine shock
30 g acceleration 11 ms duration Direction of shock: 3 axes

3 shocks in positive direction and 3 shocks in negative direction.

Time dependent course of the shock / 30 g, 11 ms
Negative direction

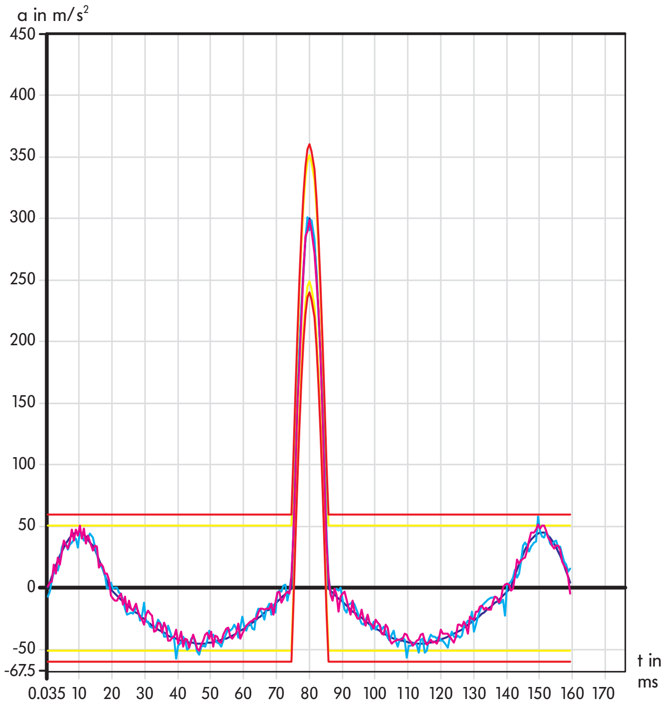


Status:	Stop
Cause:	Number of shocks ready!

Date:	06.10.2004	Control:	active
Time:	09:02:16	Total number of shocks:	3
Modulation:	82.2 %	Shocks processed:	3
Warning limits:	inactive	Top acceleration:	308.68 m/s²
Turn-off limits:	inactive	Speed:	2.09 m/s

Upper warning limits, Lower warning limits, Upper turn-off limits, Lower turn-off limits
Scheduled. curve of acc., Actual curve of acc., Measurement curve of acceleration

Time dependent course of the shock / 30 g, 11 ms
Positive direction



Status:	Stop
Cause:	Number of shocks ready!

Date:	06.10.2004	Control:	active
Time:	09:03:32	Total number of shocks:	3
Modulation:	87.5 %	Shocks processed:	3
Warning limits:	inactive	Top acceleration:	306.84 m/s²
Turn-off limits:	inactive	Speed:	2.08 m/s

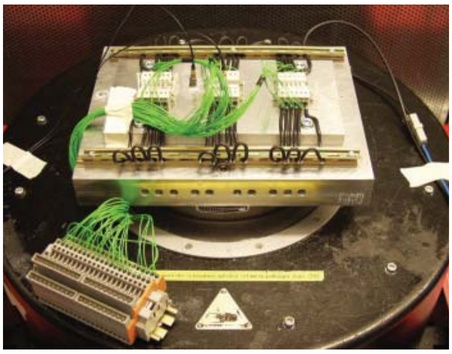
Upper warning limits, Lower warning limits, Upper turn-off limits, Lower turn-off limits
Scheduled. curve of acc., Actual curve of acc., Measurement curve of acceleration

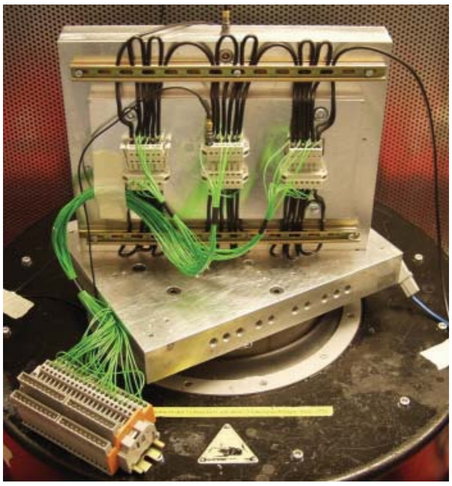
Tests and Testing Procedures According to IEC/EN Standards (continued)
Mechanical Tests (continued)

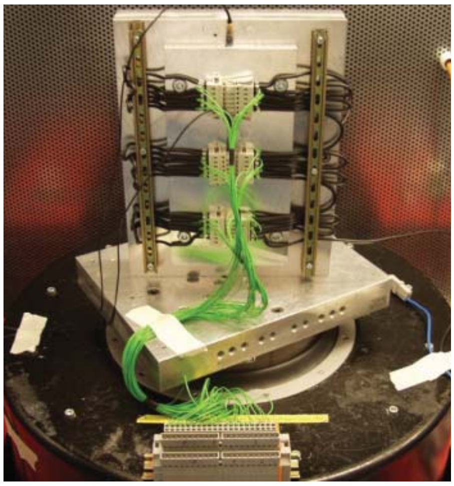
• Vibration test acc. to IEC/EN 60068-2-6; Shipbuilding GL, LR, DNV; Railway applications EN 61373

The vibration test is aimed at finding out if vibrations, such as those produced in the vicinity of machines or in vehicles, will permanently affect the electrical connection or if contact breaks will occur during vibrations. Using a vibration table, the test specimen is submitted to vibrations in each of the X, Y and Z axes (see pictures). The amplitude, the acceleration and especially the frequency of the vibrations shall vary during the test.

For example, a common test is carried out using a wide frequency band up to 2000 Hz with different accelerations up to 20 g and varying amplitudes up to 20 mm. The test duration can be 90 minutes per axis.







Other types of test are carried out using a single fixed frequency. The exact test procedure shall vary considerably depending on how the product will be used. Some test specifications require the determination of possible resonant frequencies, i.e. finding out if resonances will occur within the frequency spectrum to be passed through. Analysing the specimen behavior under the influence of resonant frequencies is carried out using a special testing procedure.

Apart from the standard tests mentioned above, special test procedures are carried out by the railway company, for example, on rolling stock electrical equipment or by shipping classification societies such as Germanischen Lloyd, Lloyd's Register of Shipping, Det Norske Veritas.
Though the requirements of such test procedures are particularly high, test arrangements are identical for all of them. During vibrations, possible contact breaks are monitored on an oscilloscope. Voltage drop is measured before and after the test to detect permanent failures, i.e. checking if the electrical resistance at the clamping unit has not increased beyond the permissible limit. The smaller this value is, the smaller the contact resistance of the clamping unit will be.

The test is passed if the conductor has neither slipped out of the terminal block nor been damaged, the maximum permissible voltage drop has not been exceeded and neither contact breaks have occured nor a defined break time has been exceeded.

After the test, the specimens should show no damage which could affect subsequent operation.