INDEPENDENT LABORATORY FOR ELECTRICAL TESTING MAREL,
VELIKO GOLOVODE bb, 37000 KRUŠEVAC, SERBIA

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ATS 01-515 TESTING LABORATORY ISO/IEC 17025

EA MLA and ILAC MRA Signatory

TYPE TESTING REPORT № 36/24

User: MAREL

Manufacturer: MAREL

Tested product - markings: Cable lugs with shear bolts for voltage grade up to 42 kV BLMT-M 35-150 mm2 / M12

Catalog No / Data Sheet No: 375925

Room temperature & RH: 23°C ±3°C 55% ±5% RH

Shear head torque range (Nm): 28 - 30

Sampled by / Date: MAREL Lab / 26.04.2024.

Number of pages: 22

Reference testing documents: **SRPS EN 61238 – 1 – 3:2019 / EN 61238 – 1– 3: 2019**

Class 1 A Connector

Kruševac; 25.06.2024.

Date

Head of Laboratory

Miljana Milenković Nikolić

MAREL CEO

Vladimir Raičević

LIST OF CONDUCTED TESTS	TEST RESULT	TEST №
1. Mechanical test		
1.1 Mechanical test (SRPS EN 61238-1-3:2020 / EN 61238-1-3:2019; clause 7)	**PASS**	**36/24-01**
2. Electrical test		
2.1 Electrical ageing test – Class A: heat cycles and short circuit test, (SRPS EN 61238-1-3:2020 / EN 61238-1-3:2019, clause 6)	**PASS**	**36/24-02**

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TESTING REPORT № 36/24 — 36/24-01

MECHANICAL TEST — TEST 1.1

User: MAREL

Manufacturer: MAREL

Tested product - markings: Cable lugs with shear bolts for voltage grade up to 42 kV BLMT-M 35-150 mm2 / M12

Catalog № / Data Sheet №: 375925

Room temperature & RH: 23,7° C, 53% RH

Sampled by / Date: MAREL Lab / 26.04.2024.

Number of pages: 6

Cables used for test: X00-0/A 150 mm2

Sample № used for this test: **1 2 3**

Reference testing documents: **SRPS EN 61238 – 1 – 3:2019 / EN 61238 – 1– 3:2019; clause 7 – Class 1 Connector**

Kruševac; 08.05.2024.

Date

Head of Laboratory

Miljana Milenković Nikolić

MAREL CEO

Vladimir Raičević

Testing procedure:

The purpose of these tests is to ensure an acceptable mechanical strength for the connections to the conductors of power cables.

NOTE: The pull-out force does not give any reliable indication of the electrical quality of the connector.

The test shall be made on three additional connectors identical to those used for the electrical test. The connectors are fitted as for the electrical test. The recommended conductor lengths, between connectors or between connector and tensile test machine jaws is ≥500 mm. The rate of application of the load shall not exceed 10 N per square millimeter of cross-sectional area and per second up to 25% of the value in Table 1, which is then maintained for 1 min.

If the connector is tested electrically for conductors with a different cross-sectional area, the different connectors shall be tested individually, in accordance with Table 1.

Equipment under test:

- **Connectors**

Table 2. - *Connectors*

Connector type (through, branch, terminal lugs)	**Terminal connector**
Type of jointing (crimping, mechanical, IPC)	**Mechanical**
Type of plating if applicable	**Tinned** Al

- **Conductors**

Table 3. - *Conductors*

Side 1 (Main) - Nominal cross section (mm2)	**150**	**Al**
Side 2 (Branch) - Nominal cross section (mm2)	**0**	**/**
Type of conductor (solid, stranded)	**Stranded**	
Shape of conductor (sectorial, circular…)	**Circular**	
Stranded conductor (compacted, non-compacted)	**Compacted**	
Stranded conductor (flexible, rigid)	**Flexible**	
Diameter of conductor (mm)	**14,4**	
Number of strands	**Not** applicable	
Diameter on insulation (mm)	**16,2**	
Material and thickness of insulation (only for IPC's)	**Not applicable**	
Maximum conductor temperature in normal operation (only for IPC's)	**Not applicable**	

- **Test arrangement**

Table 4. - *Test arrangements*

Preparation of contact surfaces	
Cable preparation before installation (dry brushing, brushing under neutral grease, no brushing…)	**Brushing under neutral grease**
Connector preparation (brushing contact palms for terminal lugs)	**Brushing palm** of lug
Connector installation	
Tooling (torque wrench, crimping dies, jack ...)	**Torque wrench**
Tightening torque for mechanical connectors (Nm)	**28 - 30**
Number of indents for crimped connector	**Not applicable**
Tightening toque on palms of terminal lugs (Nm)	**Not applicable**
Temperature of connector installation (C°)	**23,6**

Requirements:

Not more than 3 mm slippage shall occur during the last minute of the test.

Testing results:

Table 5. *– Testing results*

№	Main / Side 1 (mm^2)	Branch / Side 2 (mm^2)	Force 1 (N)	Slippage (mm)	Test score (Satisfactory / Unsatisfactory)	Examiner / Date
1	150	0	**6000**	0	**Satisfactory**	Ivan Stanković Milan Radojković 08.05.2024.
2				0	**Satisfactory**	
3				0	**Satisfactory**	

EQUIPMENT USED FOR TESTING

№	Type	Model	Latest calibration
1	Torque wrench	Unior – Model 266	05.10.2023.
2	Hydraulics crimping press	Elmark	Calibration not needed
3	Tape measuring ruler 1m	Orion 0-1000 mm	26.04.2024.
4	Caliper with digital dial	Tesa / 0.002mm – with digital dial	13.02.2024.
5	Stopwatch	JS-505A	17.05.2021.
6	Electrohydraulic tensioning system for cable accessories	AFS-MRL	/
6.1	Load cell 1 (Axis 1)	HBM U10M/125 kN	08.02.2024.
6.2	Load cell 2 (Axis 2)	HBM U10M/125 kN	08.02.2024.

DECLARATION OF CONFORMITY FOR TESTS PERFORMED (by user request):

TESTED PRODUCT IS IN COMPLIANCE WITH TESTED STANDARD CLAUSE.

OPINIONS AND INTERPRETATIONS (by user request):

Head of mechanical testing procedure:

Milan Radojković

Head of electrical testing procedure:

Vladimir Rilak

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TESTING REPORT № 36/24 — 36/24-02

ELECTRICAL AGEING TEST — TEST 2.1

User: MAREL

Manufacturer: MAREL

Tested product - markings: Cable lugs with shear bolts for voltage grade up to 42 kV BLMT-M 35-150 mm2 / M12

Catalog № / Data Sheet №: 375925

Room temperature & RH: 24,2° C, 52% RH

Sampled by / Date: MAREL Lab / 26.04.2024.

Number of pages: 14

Cables used for test: X00-0/A 150 mm2

Sample № used for this test: **4 5 6 7 8 9**

Reference testing documents: **SRPS EN 61238 – 1 – 1:2019 / EN 61238 – 1 – 1:2019, clause 6 – Class A Connector**

Kruševac; 25.06.2024.

Date

Head of Laboratory

Miljana Milenković Nikolić

MAREL CEO

Vladimir Raičević

Testing procedure:

There are six (6) connectors in test loop, connectors are installed on appropriate conductors. They are subjected to 1 000 cycles of heating and cooling with alternate current. Test is done in compliance with EN 61238-1-3 standard.

Equipment under test:

- **Connectors**

Table 1. - *Connectors*

Connector type (through, branch, terminal lugs)	**Terminal connector**
Type of jointing (crimping, mechanical, IPC)	**Mechanical**
Type of plating if applicable	**Tinned** Al

- **Conductors**

Table 2. - *Conductors*

Side 1 (Main) - Nominal cross section (mm2)	**150**	**Al**
Side 2 (Branch) - Nominal cross section (mm2)	**0**	***I***
Type of conductor (solid, stranded)	**Stranded**	
Shape of conductor (sectorial, circular…)	**Circular**	
Stranded conductor (compacted, non-compacted)	**Compacted**	
Stranded conductor (flexible, rigid)	**Flexible**	
Diameter of conductor (mm)	**14,4**	
Number of strands	**Not** applicable	
Diameter on insulation (mm)	**16,2**	
Material and thickness of insulation (only for IPC's)	**Not applicable**	
Maximum conductor temperature in normal operation (only for IPC's)	**Not applicable**	

- **Test condition**

Table 3. - *Test Conditions*

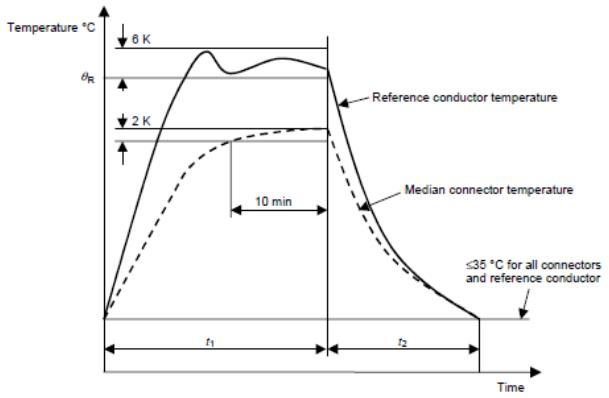
Test loop by figure	**1a**
Total number of cycles	**1000**
Class	**A**
Heating time used (min)	**25**
Cooling time used (min)	**11**
Pause time used (min)	**4**
Current value of heating start (A)	**630**
Equilibrium heating current I_N (A)	**605**
Median connector number	**7**
Median connector temperature at 1st adjusting cycle on reference cable (C°)	**55,1**
Reference cable temperature at 2nd heating cycle (C°)	**97,8**
DC current for resistance measurement (A)	**35**
Number of cycles before short circuit	**200**
Number of short circuits	**6**
Initial θ of reference cable (C°)	**22,7**
Final θ of reference cable (C°)	**89,5**
Required short-circuit vale (s)	**1,5**
Theoretical short-circuit current value (A)	**9170**

The adjustments of temperatures and currents are carried out in accordance with clause 6.3 of the standard.

- **Test arrangement**

Table 4. - *Test arrangements*

Preparation of contact surfaces		
Cable preparation before installation (dry brushing, brushing under neutral grease, no brushing…)		**Brushing under neutral grease**
Connector preparation (brushing contact palms for terminal lugs)		**Brushing palm** of lug
Connector installation		
Tooling (torque wrench, crimping dies, jack ...)		**Torque wrench**
Tightening torque for mechanical connectors (Nm)		**28 - 30**
Number of indents for crimped connector		**Not applicable**
Tightening toque on palms of terminal lugs (Nm)		**Not applicable**
Temperature of connector installation (C°)		**23,6**
Testing circuit		
Equalizers type used (welded, crimped, mechanical …)		**Welded**
Virtual length of connectors: ℓ_i (mm)		**86 / Not applicable**
Minimum distance between equalizers and test loop connection $\ell_{r\,(Al)}$ / $\ell_{r\,(Cu)}$ ($\ell_{r\,(main)}$ / $\ell_{r\,(branch)}$) (mm)		**546 / Not applicable**
Distance d between connectors (mm)		**970**
Distance between equalizers and connectors	ℓ_a (mm)	**180**
	ℓ_b (mm)	**Not** applicable
Characteristic of linking bars between lugs if used	Nature	**Not applicable**
	Cross section (mm2)	**Not applicable**
	Length (mm)	**Not applicable**
	Width (mm)	**Not applicable**
	Thickness (mm)	**Not applicable**



1. *temperature axis*
2. *reference conductor temperature θ_R*
3. *median connector temperature*
4. *temp. ≤ 35 ˚C for connectors and reference conductors*
5. *time axis*

Diagram 1. *– Second heating cycle*

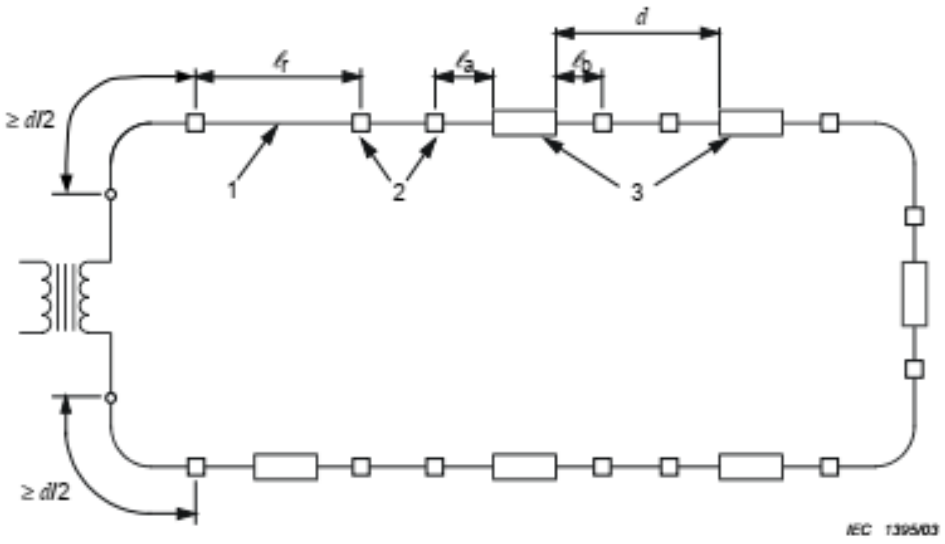


Figure 1a – Through connectors

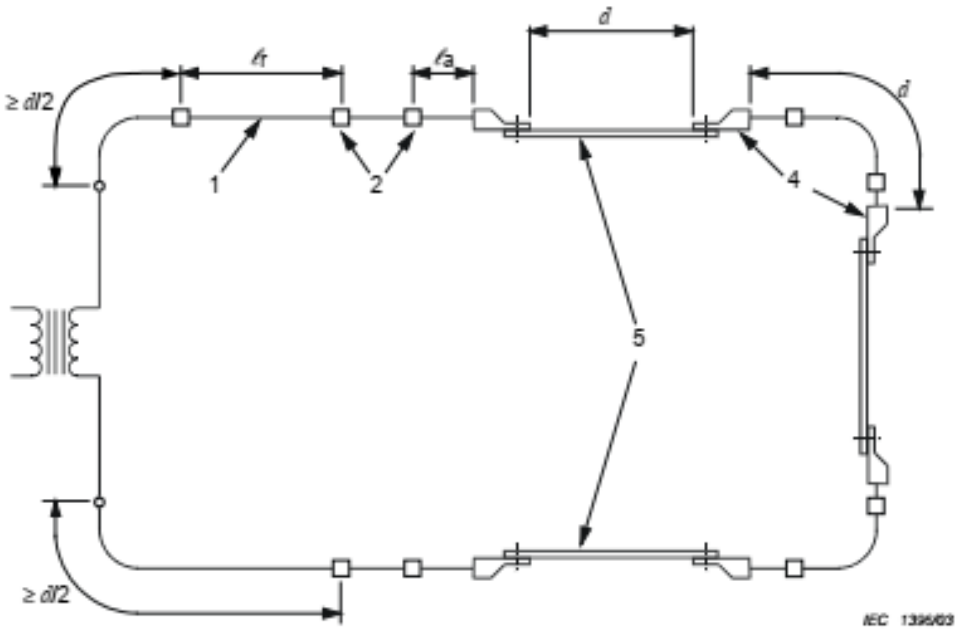


Figure 1b – Terminal lugs

where

$d \geq 80\sqrt{A}$ or 500 mm, whichever is the greater

A is the corresponding conductor cross-sectional area, in mm²

$\ell_r \geq \ell_a + \ell_b + \ell_j$ (for ℓ_j, see Figure 3)

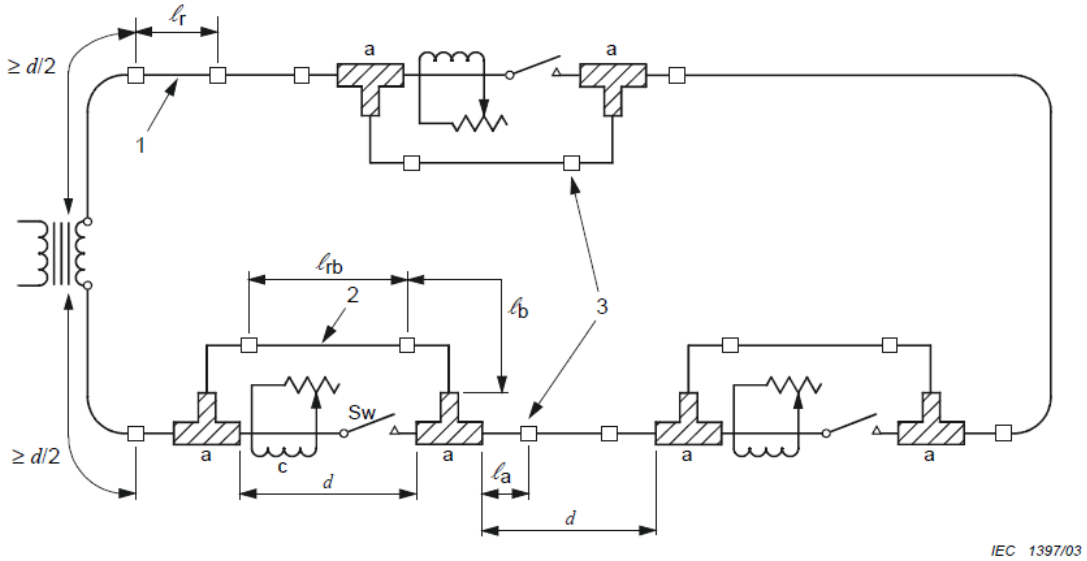
For stranded conductors:

$\ell_a, \ell_b = 15\sqrt{A}$ or 150 mm, whichever is the greater

Key

1 reference conductor
2 equalizers (for stranded conductors)
3 through connectors
4 terminal lugs
5 linking bars

Figure 1. *– Typical test circuit for through connectors and terminal lugs*



where

$d \geq 80\ \sqrt{A}$ or 500 mm, whichever is the greater

A is the main conductor sectional area, in mm²

$\ell_r,\ \ell_{rb} \geq d$

For stranded conductors:

$\ell_a,\ \ell_b \approx 15\ \sqrt{A}$ or 150 mm, whichever is the greater

NOTE For IPC ℓ_a, ℓ_b may be increased if necessary.

Key

1	main reference conductor
2	branch reference conductor
3	equalizer (for stranded conductors)
a	branch connector
c	current control;
Sw	switch (for branch resistance measurement)

Figure 2. *– Typical test circuit for branch connectors*

*** Test loop by figure 1a.**

Requirements:

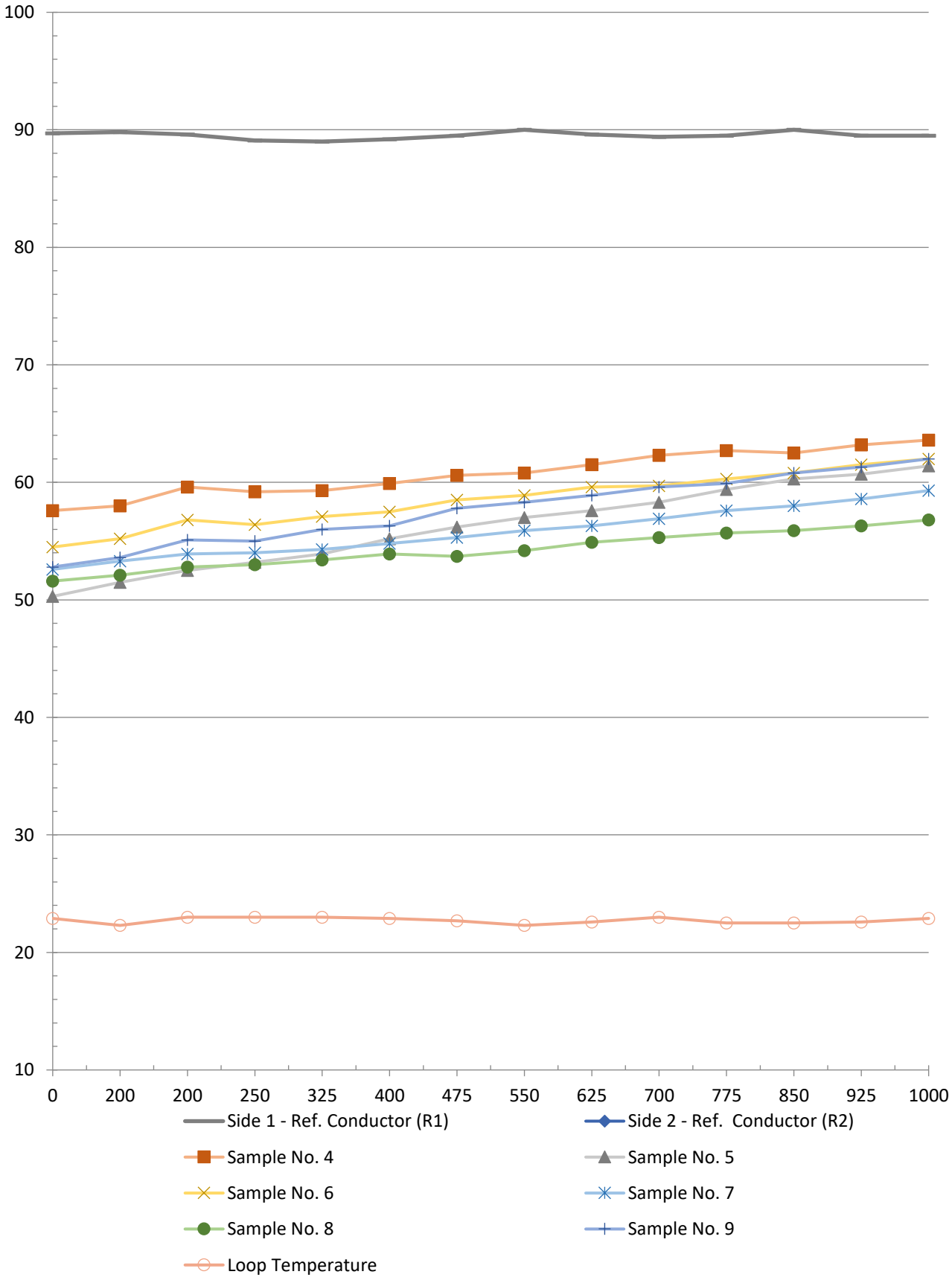
Table 5. *– Requirements*

Parameter	Maximum value
Initial scatter δ	**≤ 0,3**
Mean scatter β	**≤ 0,3**
Change in resistance factor D	**≤ 0,15**
Resistance factor ratio λ	**≤ 2**
Maximum temperature θ_{max} j of each connector	**θ_{REF}**

Testing results:

Table 6. *– Temperatures, test loop*

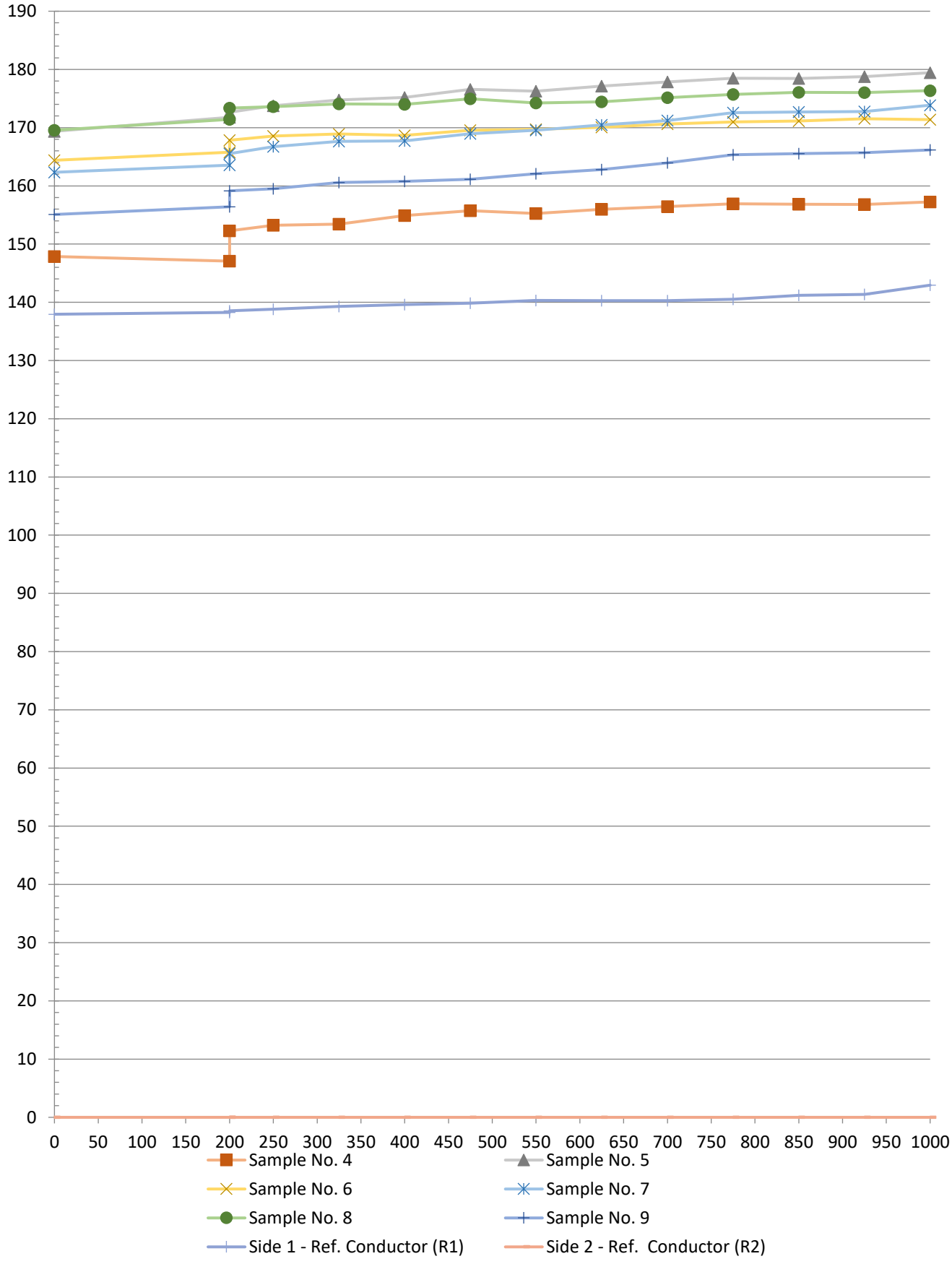
Cycle	Reference conductor R1 (°C)	Reference conductor R2 (°C)	Ambient temp. (°C)	Sample № 4	5	6	7	8	9
				θj (°C)	θj (°C)	θj (°C)	θj (°C)	θj (°C)	θj (°C)
0	89,6	/	22,7	57,4	50,3	54,3	52,6	51,6	52,8
200	89,8	/	22,1	58,0	51,5	55,2	53,3	52,1	52,6
200	89,2	/	23,0	59,5	52,5	56,6	53,9	52,8	55,1
250	89,1	/	23,0	59,1	53,2	56,4	54,0	53,0	55,0
325	89,0	/	23,0	59,3	53,9	57,1	54,3	53,3	56,0
400	89,1	/	22,6	59,7	55,2	57,3	54,8	53,9	56,3
475	89,2	/	22,7	60,5	56,2	58,5	55,3	53,7	57,8
550	89,7	/	22,3	60,6	57,0	58,7	55,9	54,2	58,3
625	89,2	/	22,6	61,5	57,6	59,4	56,3	54,9	58,4
700	89,4	/	23,0	62,3	58,3	59,7	56,8	55,3	59,6
775	89,3	/	22,3	62,4	59,4	60,3	57,5	55,4	59,9
850	90,0	/	22,5	62,5	60,3	60,8	58,0	55,9	60,8
925	89,5	/	22,4	63,1	60,7	61,5	58,6	56,3	60,3
1000	89,5	/	22,9	63,5	61,4	62,0	59,3	56,4	62,0



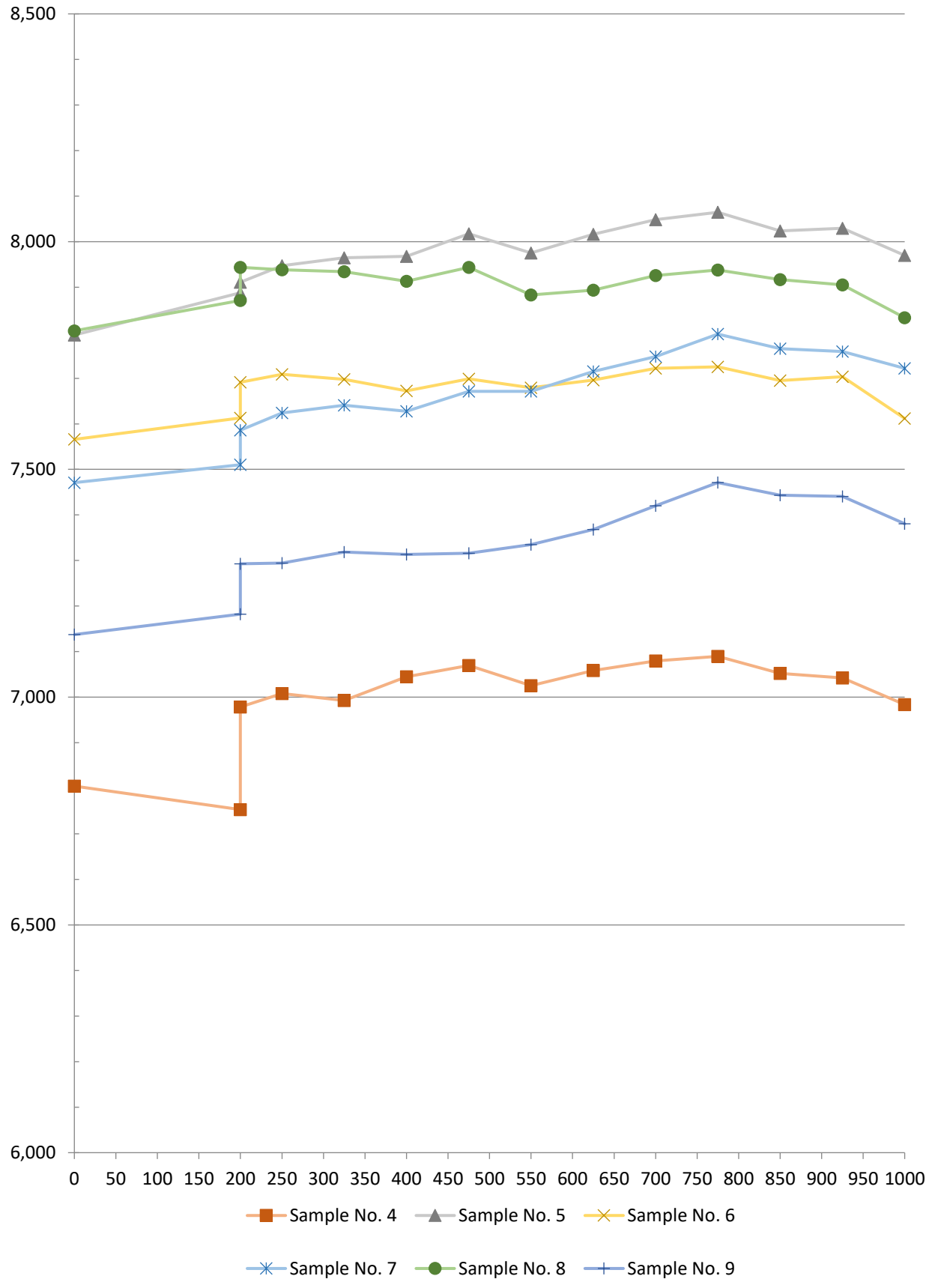
Temperature diagram (class A) – Test Loop

Table 7. *– Resistance, test loop*

Cycle	Sample № 1			2			3			Ref. (R1)	
	R (μΩ)	k	R ratio: λ	R (μΩ)	k	R ratio: λ	R (μΩ)	k	R ratio: λ	R (μΩ)	λ≤ 2
0	147,852	6,805	/	169,372	7,795	/	164,393	7,566	/	137,949	
200	**147,057**	**6,753**	**0,992**	**171,775**	**7,888**	**1,012**	**165,793**	**7,613**	**1,006**	**138,262**	
200	**152,288**	**6,979**	**1,026**	**172,637**	**7,911**	**1,015**	**167,848**	**7,691**	**1,017**	**138,548**	
250	153,243	7,008	1,030	173,780	7,947	1,020	168,574	7,691	1,019	138,831	
325	153,434	6,993	1,028	174,757	7,964	1,022	168,898	7,697	1,017	139,307	
400	154,890	7,045	1,035	175,182	7,968	1,022	168,690	7,672	1,014	139,590	
475	155,722	7,070	1,039	176,588	8,017	1,028	169,571	7,699	1,018	139,841	
550	155,272	7,025	1,032	176,260	7,975	1,023	169,723	7,679	1,015	140,317	
625	155,976	7,059	1,037	177,143	8,016	1,028	170,070	7,696	1,017	140,293	
700	156,438	7,079	1,040	177,856	8,049	1,033	170,633	7,722	1,021	140,296	
775	156,917	7,090	1,042	178,494	8,064	1,035	170,985	7,725	1,021	140,521	
850	156,840	7,052	1,036	178,437	8,023	1,029	171,129	7,695	1,017	141,195	
925	156,805	7,042	1,035	178,781	8,029	1,030	171,526	7,703	1,018	141,364	
1000	157,243	6,984	1,026	179,442	7,970	1,022	171,377	7,612	1,006	142,943	
$\overline{Rj}$ $\overline{kj}$	**155,7073**	**7,0362**		**176,9746**	**8,0034**		**169,1108**	**7,6562**			
b		0,0018			0,0064			-0,0027			
M		0,0025			0,0081			-0,0035			
S		0,0106			0,0088			0,0084			
D		**0,0131**			**0,0169**			**0,0119**			**≤ 0,15**
Cycle	4			5			6			Ref. (R2)	
0	162,330	7,471	/	169,571	7,804	/	155,083	7,137	/	/	
200	**163,556**	**7,510**	**1,005**	**171,414**	**7,871**	**1,009**	**156,414**	**7,196**	**1,026**	/	
200	**165,545**	**7,586**	**1,015**	**172,854**	**7,932**	**1,018**	**159,125**	**7,274**	**1,026**	/	
250	166,718	7,624	1,021	173,593	7,939	1,017	159,507	7,294	1,022	/	
325	167,657	7,641	1,023	174,092	7,934	1,017	160,584	7,319	1,025	/	
400	167,706	7,628	1,021	173,985	7,913	1,014	160,791	7,313	1,025	/	
475	168,973	7,671	1,027	174,965	7,944	1,018	161,138	7,316	1,025	/	
550	169,543	7,671	1,027	174,221	7,883	1,010	162,105	7,335	1,028	/	
625	170,478	7,715	1,033	174,429	7,894	1,011	162,816	7,368	1,032	/	
700	171,211	7,748	1,037	175,140	7,926	1,016	163,967	7,420	1,040	/	
775	172,574	7,797	1,044	175,693	7,938	1,017	165,360	7,471	1,047	/	
850	172,687	7,765	1,039	176,060	7,917	1,014	165,534	7,443	1,043	/	
925	172,762	7,759	1,039	176,016	7,905	1,013	165,680	7,441	1,043	/	
1000	173,857	7,722	1,034	176,362	7,833	1,004	166,172	7,381	1,034	/	
$\overline{Rj}$ $\overline{kj}$	**170,3681**	**7,7632**		**174,9597**	**7,9147**		**163,0596**	**7,34238**			
b		0,0155			-0,0055			0,0155			
M		0,0201			-0,0069			0,0210			
S		0,0089			0,0074			0,0104			
D		**0,0289**			**0,0143**			**0,0315**			**≤ 0,15**



Resistance diagram (class A) – Test loop



K ratio diagram (class A) – Test loop

Table 8. *– Results, test loop*

$\bar{K}$	7,6217	
$\overline{Ko}$	7,4269	
So	0,3856	
δ	0,0872	**≤ 0,3**
S	0,3545	
β	0,0736	**≤ 0,3**

Table 9. *– Results – Conclusion, test loop*

Parameter	Results	Maximum value
Initial scatter *δ*	Table 8	≤ 0.3
Mean scatter *β*	Table 8	≤ 0.3
Assessment of resistance stability	Table 7	≤ 0,15
Resistance factor ratio *λ*	Table 7	≤ 2
Maximum temperature θ_{max} of each connector	Table 6	θ_{max}

Examiner / Date	
Petar Milićević	
Ivan Stanković	
Dušan Radivojević	
25.06.2024.	

Expanded measurement uncertainty U = 1,01 % *(exp. measurement uncertainty 95% - ILAC G8)*

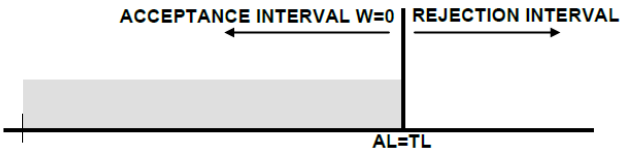
EQUIPMENT USED FOR TESTING

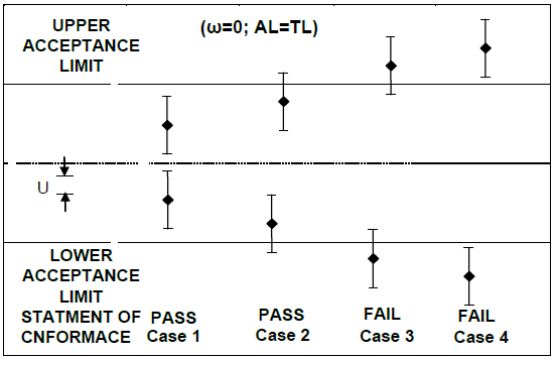
№	Type	Model	Latest calibration
1	Torque wrench	Unior – Model 266	05.10.2023.
2	Hydraulics crimping press	Elmark	Calibration not needed
3	Tape measuring ruler 1m	Orion 0-1000 mm	26.04.2024.
4	Caliper with digital dial	Tesa / 0.002mm – with digital dial	13.02.2024.
5	Electrical ageing test bench	UES-185	Calibration not needed
5.1	Millivoltmeter	MVC-109-8	13.01.2021.
5.2	Temperature regulator	Termomir BP-10	22.12.2023.
5.3	Temperature regulator	Termomir BP-10-2	22.12.2023.
5.4	Temperature regulator	Termomir BP-10-8	22.12.2023.
5.5	Time relay	ETI CRM-91H	23.03.2022.
6	Digital multimeter	Fluke 289	01.11.2021.

DECISION RULE:

BINARY STATEMENT FOR SIMPLE ACCEPTANCE RULE
Ω = 0 – Guard band equal zero, AL = TL

Standard ILAC – G8:09/19, Clause 4.2.1





DECLARATION OF CONFORMITY FOR TESTS PERFORMED (by user request):

TESTED PRODUCT IS IN COMPLIANCE WITH TESTED STANDARD CLAUSE.

OPINIONS AND INTERPRETATIONS (by user request):

Head of mechanical testing procedure:

Milan Radojković

Head of electrical testing procedure:

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