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

Tel/fax: 037 3566 262, 037 3566 266
www.marellaboratory.rs; e-mail: laboratory@marel.rs;
marellaboratory@gmail.com

ATS 01-515 TESTING LABORATORY ISO/IEC 17025

EA MLA and ILAC MRA Signatory

TYPE TESTING REPORT № 43.2/23

User: MAREL

Manufacturer: MAREL

Tested product - markings: Cable lugs with shear bolts for voltage grade up to 42 kV
BLMT-M 95-240 mm2 M16

Catalog No / Data Sheet No: 375933

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

Shear head torque range (Nm): 35 - 38

Sampled by / Date: MAREL Lab / 24.11.2023.

Number of pages: 22

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

Class A Connector

Kruševac; 20.12.2023.

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 61238-1:2010 / EN 61238-1:20034:2009; clause 7)	**PASS**	**43.2/23-01**
2. Electrical test		
2.1 Electrical ageing test – Class A: heat cycles and short circuit test, (SRPS EN 61238-1:2010 / EN 61238-1:2003, clause 6)	**PASS**	**43.2/23-02**

NEZAVISNA LABORATORIJA ZA ELEKTROTEHNIČKA ISPITIVANJA

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TESTING REPORT № 43.2/23 — 43.2/23-01

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 95-240 mm2 M16

Catalog № / Data Sheet №: 375933

Room temperature & RH: 22,1° C, 53% RH

Sampled by / Date: MAREL Lab / 24.11.2023.

Number of pages: 6

Cables used for test: ACSR 240 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**

Kruševac; 27.11.2023.
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 of 6.1. The conductor lengths, between connectors or between connector and tensile test machine jaws, shall be ≥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 the value in Table 3, 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.

***Table 1**. Tensile forces (*tolerance of applied forces is ± 5%)

Conductor material	Tensile force (N)
Aluminum	40 x A[a]; maximum 20000
Copper	60 x A[a]; maximum 20000

[a] A = nominal cross-sectional area (mm^2).

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)	**240**	**Al**
Side 2 (Branch) - Nominal cross section (mm2)	**/**	**/**
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)	**21,9**	
Number of strands	**26 / 7**	
Diameter on insulation (mm)	**Not applicable**	
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)	**Not applicable**
Connector installation	
Tooling (torque wrench, crimping dies, jack ...)	**Torque wrench**
Tightening torque for mechanical connectors (Nm)	**35 - 38**
Number of indents for crimped connector	**Not applicable**
Tightening toque on palms of terminal lugs (Nm)	**Not applicable**
Temperature of connector installation (C°)	**22**

Requirements:

No slipping 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	240	/	**9600**	0	**Satisfactory**	Dušan Radivojević
2				0	**Satisfactory**	Ivan Stanković
3				0	**Satisfactory**	27.11.2023.

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	13.05.2021.
4	Caliper with digital dial	Tesa / 0.002mm – with digital dial	25.02.2021.
5	Stopwatch	JS-505A	17.05.2021.
4	Tensile machine with one axis dynamometer	Axis / Zemic FB20K/H3C3-3.0t-6B	24.03.2021.
5	Electrohydraulic tensioning system for cable accessories	AFS-MRL	
5.1	Load cell 1 (Axis 1)	HBM U10M/125 kN	24.03.2021.
5.2	Load cell 2 (Axis 2)	HBM U10M/125 kN	24.03.2021.
5.3	Weight 20 kg – 01	Marel	05.04.2022.
5.4	Weight 20 kg – 02	Marel	05.04.2022.
5.5	Thermocouple K1	ICS controller A10	18.04.2022.
5.6	Thermocouple K2	ICS controller A10	18.04.2022.
5.7	Thermocouple K3	ICS controller A10	18.04.2022.
5.8	Thermocouple K4	ICS controller A10	18.04.2022.
5.9	Test transformer	Amper KV T01	Calibration not needed

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 № 43.2/23 — 43.2/23-02

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 95-240 mm2 M16

Catalog № / Data Sheet №: 375933

Room temperature & RH: 22,5° C, 54% RH

Sampled by / Date: MAREL Lab / 24.11.2023.

Number of pages: 14

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

Reference testing documents: **SRPS EN 61238 – 1:2010 / EN 61238 – 1:2003, clause 6 – Class A Connector**

Kruševac; 04.04.2023.
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 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)	**240**	**Al**
Side 2 (Branch) - Nominal cross section (mm2)	**/**	**/**
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)	**21,9**	
Number of strands	**26 / 7**	
Diameter on insulation (mm)	**Not applicable**	
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*

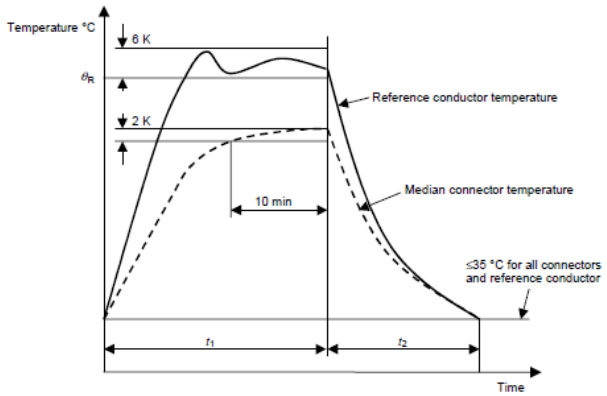
Test loop by figure	**1a**
Total number of cycles	**1000**
Class	**A**
Heating time used (min)	**33**
Cooling time used (min)	**14**
Pause time used (min)	**4**
Current value of heating start (A)	**760**
Equilibrium heating current I_N (A)	**720**
Median connector number	**8**
Median connector temperature at 1st adjusting cycle on reference cable (C°)	**72,4**
Reference cable temperature at 2nd heating cycle (C°)	**117,9**
DC current for resistance measurement (A)	**36**
Number of cycles before short circuit	**200**
Number of short circuits	**6**
Initial θ of reference cable (C°)	**22,8**
Final θ of reference cable (C°)	**118,6**
Required short-circuit vale (s)	**4,5**
Theoretical short-circuit current value (A)	**9160**

The adjustments of temperatures and currents are caried 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)		**Not applicable**
Connector installation		
Tooling (torque wrench, crimping dies, jack ...)		**Torque wrench**
Tightening torque for mechanical connectors (Nm)		**35 - 38**
Number of indents for crimped connector		**Not applicable**
Tightening toque on palms of terminal lugs (Nm)		**Not applicable**
Temperature of connector installation (C°)		**22**
Testing circuit		
Equalizers type used (welded, crimped, mechanical …)		**Welded**
Virtual length of connectors: ℓ_i (mm)		**112 / Not applicable**
Minimum distance between equalizers and test loop connection $\ell_{r\,(Al)}$ / $\ell_{r\,(Cu)}$ ($\ell_{r\,(main)}$ / $\ell_{r\,(branch)}$) (mm)		**700 / Not applicable**
Distance d between connectors (mm)		**1230**
Distance between equalizers and connectors	ℓ_a (mm)	**230**
	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*

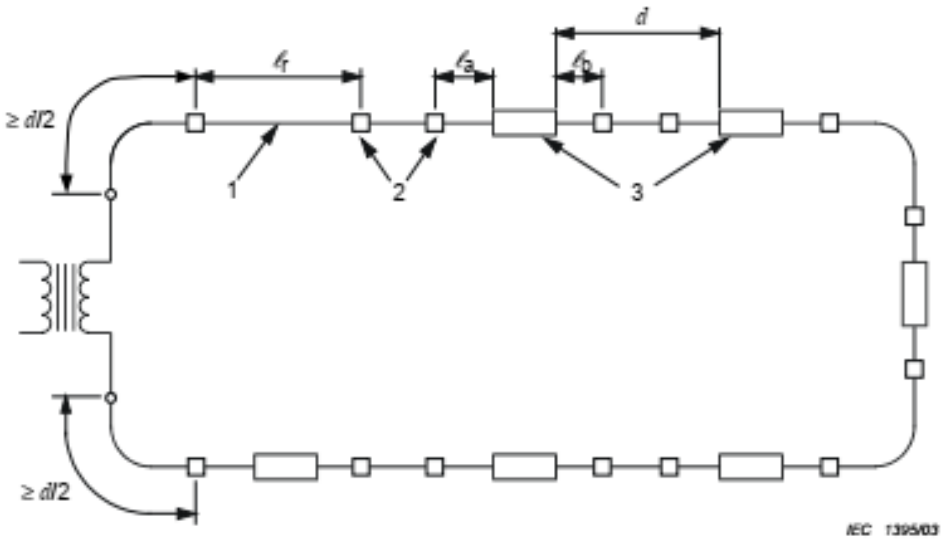


Figure 1a – Through connectors

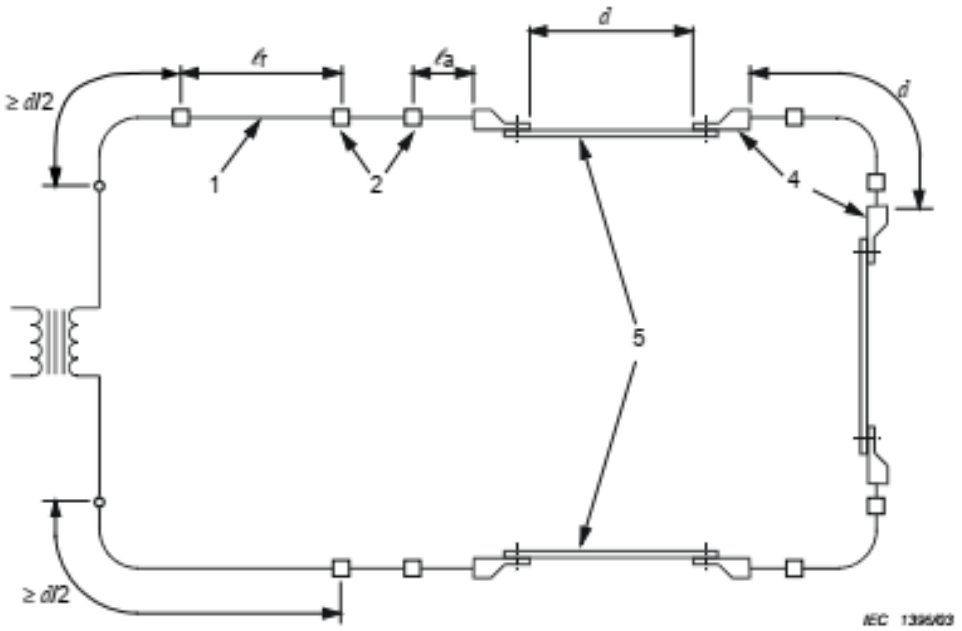


Figure 1b – Terminal lugs

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)

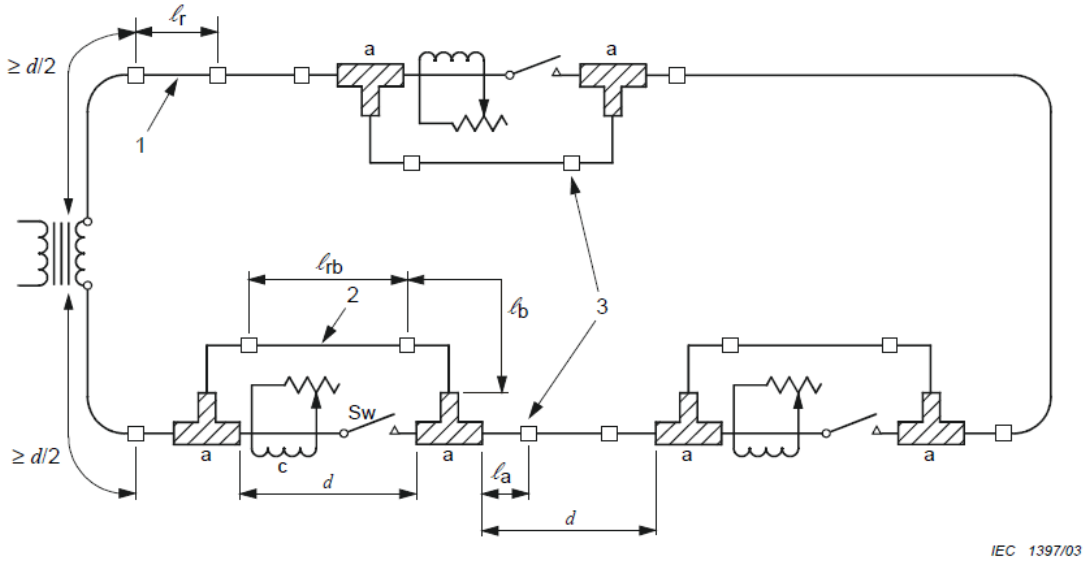
For stranded conductors:

$\ell_a, \ell_b = 15\sqrt{A}$ 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:

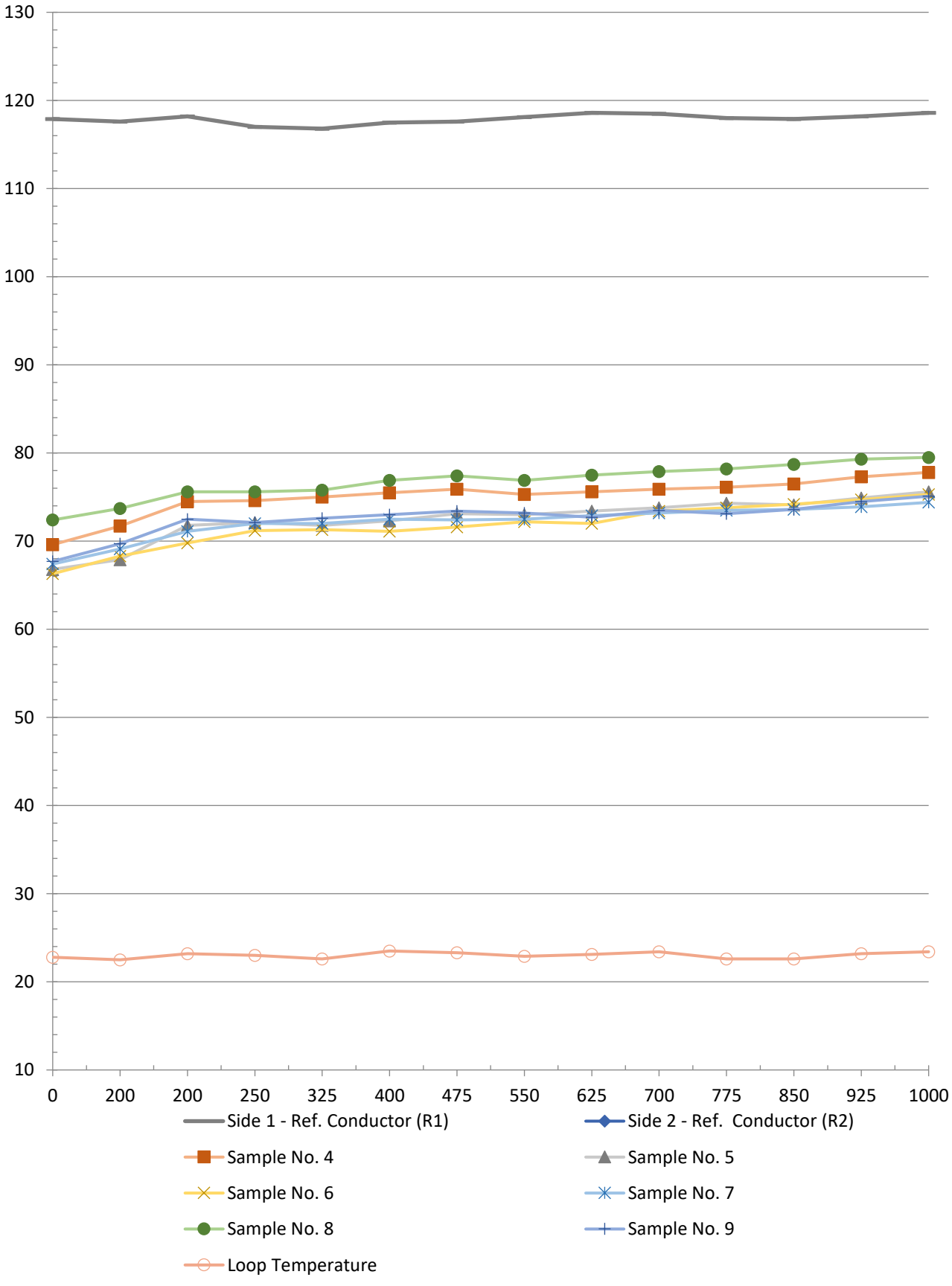
Table 5. *– Requirements*

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	117,9	/	22,8	69,6	66,8	66,3	67,4	72,4	67,7
200	117,6	/	22,5	71,7	67,9	68,3	69,1	73,7	69,7
200	118,2	/	23,2	74,5	71,8	69,8	71,1	75,6	72,5
250	117,0	/	23,0	74,6	72,1	71,2	72,0	75,6	72,1
325	116,8	/	22,6	75,0	71,8	71,3	72,0	75,8	72,6
400	117,5	/	23,5	75,5	72,3	71,1	72,5	76,9	73,0
475	117,6	/	23,3	75,9	73,1	71,6	72,4	77,4	73,4
550	118,1	/	22,9	75,3	73,0	72,2	72,5	76,9	73,2
625	118,6	/	23,1	75,6	73,4	72,0	72,9	77,5	72,7
700	118,5	/	23,4	75,9	73,8	73,4	73,2	77,9	73,5
775	118,0	/	22,6	76,1	74,3	73,8	73,5	78,2	73,1
850	117,9	/	22,6	76,5	74,1	74,2	73,6	78,7	73,6
925	118,2	/	23,2	77,3	74,9	74,7	73,9	79,3	74,5
1000	118,6	/	23,4	77,8	75,6	75,3	74,4	79,5	75,1

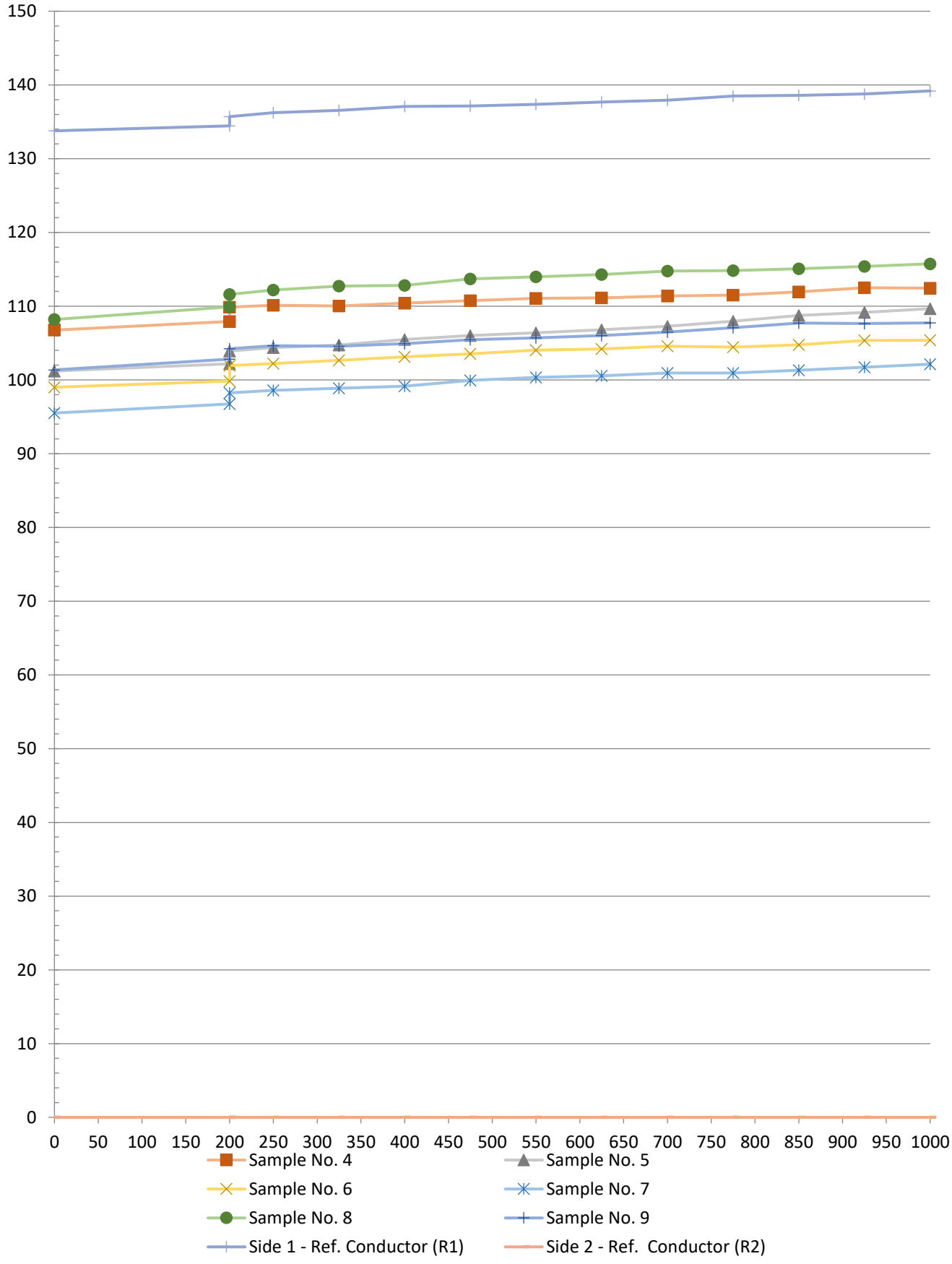


Temperature diagram (class A) – Test Loop

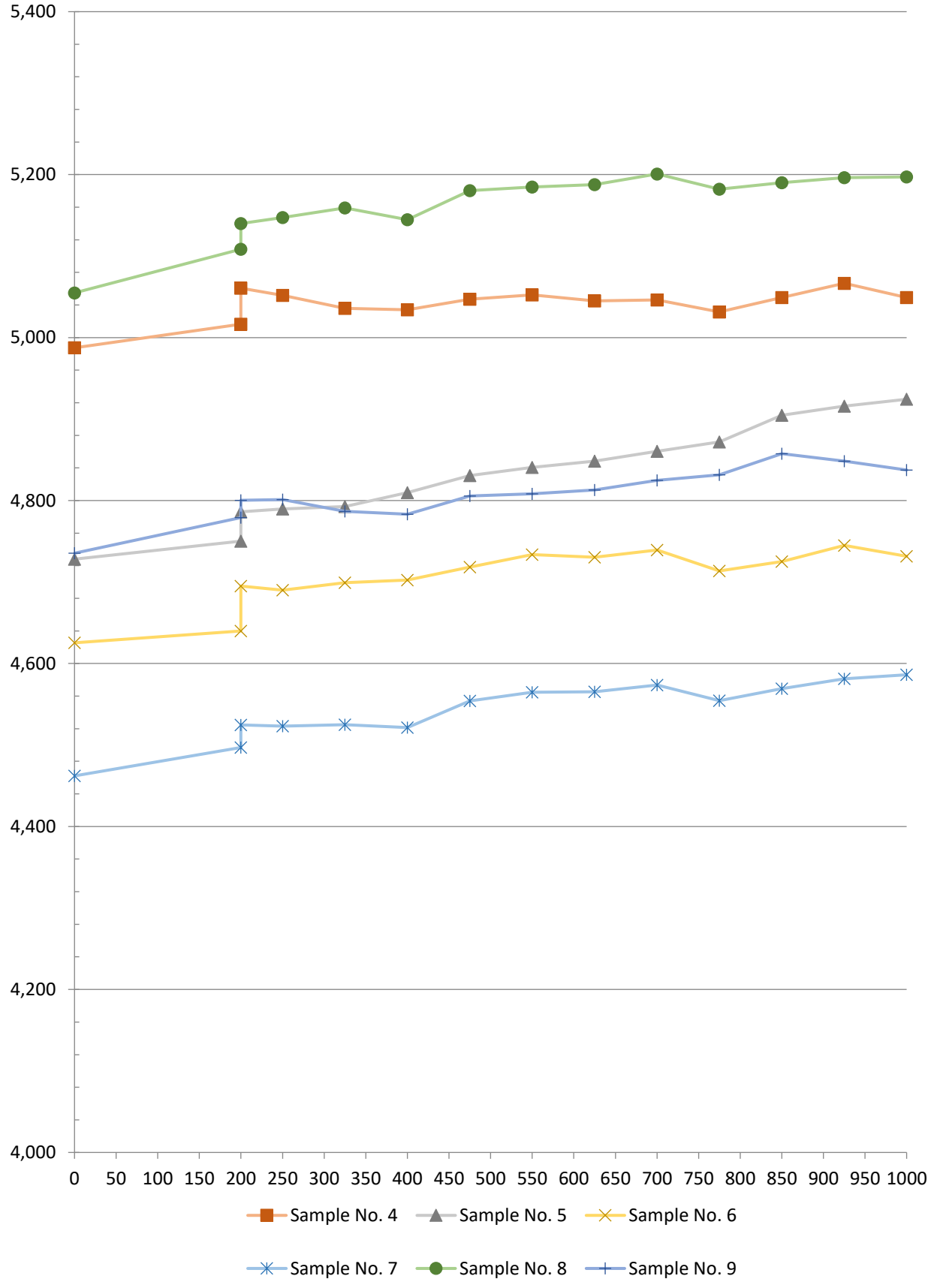
Table 7. *– Resistance, test loop*

Cycle	Sample № 1			Sample № 2			Sample № 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	106,755	4,987	/	101,203	4,728	/	99,006	4,625	/	133,779	
200	**107,923**	**5,016**	**1,006**	**102,197**	**4,750**	**1,005**	**99,825**	**4,640**	**1,003**	**134,464**	
200	**109,876**	**5,061**	**1,015**	**103,917**	**4,786**	**1,012**	**101,936**	**4,695**	**1,015**	**135,697**	
250	110,110	5,052	1,013	104,396	4,790	1,013	102,225	4,695	1,014	136,225	
325	110,026	5,036	1,010	104,716	4,793	1,014	102,671	4,699	1,016	136,554	
400	110,404	5,034	1,009	105,484	4,810	1,017	103,134	4,702	1,017	137,074	
475	110,763	5,047	1,012	106,016	4,831	1,022	103,550	4,718	1,020	137,160	
550	111,056	5,052	1,013	106,406	4,841	1,024	104,052	4,734	1,023	137,380	
625	111,136	5,045	1,012	106,802	4,848	1,025	104,205	4,730	1,023	137,681	
700	111,365	5,046	1,012	107,266	4,861	1,028	104,587	4,739	1,025	137,927	
775	111,500	5,031	1,009	107,963	4,872	1,030	104,454	4,714	1,019	138,504	
850	111,957	5,049	1,012	108,758	4,905	1,037	104,772	4,725	1,022	138,586	
925	112,503	5,067	1,016	109,157	4,916	1,040	105,360	4,745	1,026	138,779	
1000	112,448	5,049	1,012	109,668	4,924	1,042	105,376	4,732	1,023	139,191	
$\overline{Rj}$ / $\overline{kj}$	**111,2061**	**5,0463**		**106,9664**	**4,8536**		**104,0350**	**4,7208**			
b		0,0011			0,0141			0,0041			
M		0,0021			0,0291			0,0087			
S		0,0040			0,0028			0,0052			
D		**0,0061**			**0,0319**			**0,0139**			**≤ 0,15**

Cycle	Sample № 4			Sample № 5			Sample № 6			Ref. (R2)
0	95,511	4,462	/	108,198	5,055	/	101,360	4,735	/	/
200	**96,747**	**4,497**	**1,008**	**109,904**	**5,108**	**1,011**	**102,816**	**4,779**	**1,009**	/
200	**98,237**	**4,525**	**1,014**	**111,595**	**5,140**	**1,017**	**104,225**	**4,800**	**1,014**	/
250	98,590	4,523	1,014	112,194	5,147	1,018	104,647	4,801	1,014	/
325	98,865	4,525	1,014	112,720	5,159	1,021	104,581	4,787	1,011	/
400	99,161	4,521	1,013	112,830	5,145	1,018	104,908	4,783	1,010	/
475	99,942	4,554	1,021	113,687	5,180	1,025	105,464	4,806	1,015	/
550	100,336	4,565	1,023	113,965	5,185	1,026	105,689	4,808	1,015	/
625	100,568	4,565	1,023	114,280	5,188	1,026	106,028	4,813	1,016	/
700	100,934	4,574	1,025	114,774	5,201	1,029	106,478	4,825	1,019	/
775	100,931	4,555	1,021	114,837	5,182	1,025	107,074	4,832	1,020	/
850	101,314	4,569	1,024	115,085	5,190	1,027	107,710	4,858	1,026	/
925	101,723	4,581	1,027	115,381	5,196	1,028	107,657	4,848	1,024	/
1000	102,138	4,586	1,028	115,743	5,197	1,028	107,735	4,838	1,022	/
$\overline{Rj}$ / $\overline{kj}$	**100,4092**	**4,5562**		**114,1360**	**5,1791**		**106,1793**	**4,8180**		
b		0,0063			0,0050			0,0065		
M		0,0138			0,0097			0,0136		
S		0,0050			0,0045			0,0048		
D		**0,0188**			**0,0142**			**0,0184**		**≤ 0,15**



Resistance diagram (class A) – Test loop



K ratio diagram (class A) – Test loop

Table 8. *– Results, test loop*

$\bar{K}$	4,8623	
$\overline{Ko}$	4,7656	
So	0,2222	
δ	0,0769	**≤ 0,3**
S	0,2236	
β	0,0759	**≤ 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
Vladimir Rilak
Milan Radojković
Ivan Stanković
20.12.2023.

Expanded measurement uncertainty U = 0,86 % *(exp. measurement uncertainty 95% - ILAC G8)*

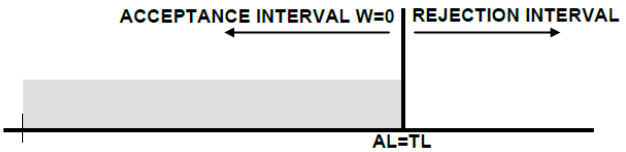
EQUIPMENT USED FOR TESTING

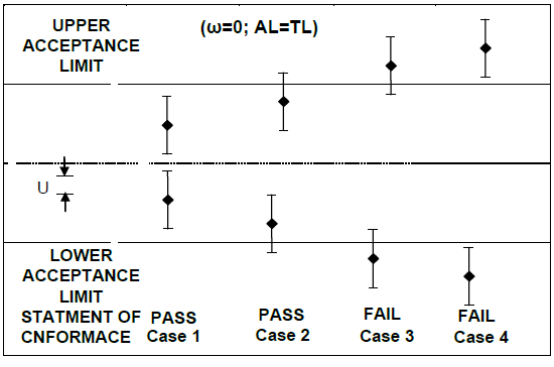
№	Type	Model	Latest calibration
1	Torque wrench	Unior – Model 266	05.10.2023.
2	Hydraulics crimping press	Elmark	Calibration not needed
3	Tape measuring ruler 1m	Orion 0-1000 mm	13.05.2021.
4	Caliper with digital dial	Tesa / 0.002mm – with digital dial	25.02.2021.
5	Electrical ageing test bench	UES-185	Calibration not needed
5.1	Millivoltmeter	MVC-109-8	13.01.2021.
5.2	Temperature regulator	Termomir BP-10	29.12.2020.
5.3	Temperature regulator	Termomir BP-10-2	29.12.2020.
5.4	Temperature regulator	Termomir BP-10-8	29.12.2020.
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:

Vladimir Rilak