Type test report no. VR/R/VM/M 5E 001e

Mechanical tests of
tap selector and change-over selector

Product Approval
CTTP/Wag
10.02.2017

Type test for types:	Tap selectors of sizes “RC”, “RD” and “RDE” without change-over selector, with reversing change-over selector or with coarse change-over selector, designed with 1, 2 or 3 current paths (connected in parallel) for use in combination with single phase, 2 phase or 3 phase diverter switches type VACUTAP® VR, VACUTAP® VM, OILTAP® R or OILTAP® M.
Test specification:	IEC 60214-1:2014, sub-clause 5.2.6: “Mechanical tests”.
Test samples:	1: VACUTAP® VM III 650 Y – 72.5/RDE – 10 19 3WP, S/N: 1601174. 2: OILTAP® R I 3003 – 362/RDE – 18 35 3GP, S/N 1547816.
Manufacturer:	Maschinenfabrik Reinhausen GmbH, Regensburg, Germany.
Date of test:	May 2015 to June 2015.
Place of test:	Maschinenfabrik Reinhausen GmbH, Regensburg, Germany.

Tests performed:

Simulation of transformer drying procedure:	Drying procedure according to the instructions of the manufacturer.
Mechanical endurance test (incl. sequence test):	300,000 operations performed in transformer oil at temperature ≥ 75 °C, 200,000 operations performed in transformer oil at temperature < 75 °C (total number of operations: 500,000). The switching sequence was measured at the beginning and at the end of the mechanical endurance test.
Operation test at 105 °C:	200 operations performed in transformer oil at 105 °C. The switching sequence was measured at the beginning and at the end of the test.
	The tests were performed with test sample 1 and test sample 2.
Test results:	The requirements of IEC 60214-1:2014 were met, i.e.: The simulation of the transformer drying procedure, the mechanical endurance test, the sequence test and the operation test at 105 °C were passed successfully.

This report contains 40 sheets.

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1. Test specification

The type test was performed in accordance with IEC 60214-1:2014 “Tap-changers - Part 1: Performance requirements and test methods”, sub-clause 5.2.6: „Mechanical tests”.

2. Data of test sample

Test sample no.:	**1**
On-load tap changer:	VACUTAP® VM III 650 Y – 72.5/RDE – 10 19 3WP
Serial no.:	1601174
IBASE:	494276614, 495141012
Year of manufacture:	2015
Part of test:	Tap selector
Test sample no.:	**2**
On-load tap changer:	OILTAP® R I 3003 – 362/RDE – 18 35 3GP
Serial no.:	1547816
IBASE:	503729042, 495141026
Year of manufacture:	2015
Part of test:	Tap selector

3. Scope of application

Tap selectors of sizes “RC”, “RD” and “RDE” are designed on the principle of a modular system for use in combination with diverter switches type VACUTAP® VR, VACUTAP® VM, OILTAP® R or OILTAP® M. The modular design of the tap selectors allows a wide range of different variations like:

- number of contacts,
- number of contact planes,
- number of parallel current paths (per phase),
- type of change-over selector (reversing change-over selector, coarse change-over selector or without change-over selector)
- change-over selector equipped with or without snap switch.

The mechanical stress (bending stress, torques, frictional forces, mechanical wear etc.) of tap selector and change-over selector components, such as tap selector column, bars, gear system and contacts is highest at following characteristics:

- highest axial dimension (highest bending stress),
- lowest number of contact bars (lowest stability of the selector cage),
- maximum number of parallel contact planes (highest torque and highest bending stress),
- maximum number of contacts (highest weight load),
- lowest number of operating positions (maximum contact wear) and
- equipped with a potential switch (additional torque load).

The mechanical tests were performed with two test samples (see sub-clause 2). The test samples cover the complete range of possible mechanical stresses listed above, within the type range of tap selectors of sizes “RC”, “RD” and “RDE” combined with diverter switches type VACUTAP® VR, VACUTAP® VM, OILTAP® R or OILTAP® M. The sequence tests were carried out with and without snap switch.
Therefore this type test report is valid for all available tap selector variants with following characteristics:

-	Tap selector size:	“RC”, “RD” or “RDE”
-	Change-over selector:	without, reversing or coarse change-over selector
-	Combined diverter switch:	VACUTAP® VR, VACUTAP® VM, OILTAP® R or OILTAP® M
-	Maximum rated through-current:	1300 A, 2000 A, 2600 A and 3000 A
-	Number of tap selector contacts:	10, 12, 14, 16 or 18
-	Number of phases:	1, 2 or 3
-	Parallel current paths (per phase):	1, 2 or 3
-	Potential switch:	with or without potential switch
-	Change-over selector snap switch:	with or without change-over selector snap switch

4. Test arrangement

4.1 Simulation of the transformer drying procedure

Prior the mechanical endurance test a transformer drying procedure according to the instructions of the manufacturer (MR) was simulated with test sample 1 and test sample 2.

The test samples were placed in a drying vessel of a drying apparatus and dried according to the drying instructions.

4.2 Mechanical endurance test (incl. sequence test)

Test conditions:	The test was performed with sample 1 and test sample 2. The test samples were assembled in a manner similar to that in service. The contacts were not energized.
Oil compartment oil filling:	Transformer oil mixture (Shell Diala D / Nynas Nitro Taurus).
Test setup:	See appendix, picture 1 and 2 (exemplary for test sample 1).
Measurement of oil temperature:	During the test the oil temperature was measured by resistance thermometers (Pt-1000).
Recording and evaluation:	The tests were recorded and evaluated by a transient recorder.

4.3 Operation test at 105 °C

Test conditions:	The test was performed with sample 1 and test sample 2. The test samples were assembled in a manner similar to that in service. The contacts were not energized.
Oil compartment oil filling:	Transformer oil mixture (Shell Diala D / Nynas Nitro Taurus).
Test setup:	See appendix, picture 1 and 2 (exemplary for test sample 1).
Measurement of oil temperature:	During the test the oil temperature was measured by resistance thermometers (Pt-1000).
Recording and evaluation:	The tests were recorded and evaluated by a transient recorder.

5. Tests performed

5.1 Simulation of the transformer drying procedure

	Test sample 1	Test sample 2
Drying method:	Kerosene drying procedure	
Heating phase with pressure lowering:	37.5 h (100 – 135 °C)	24.5 h (100 – 135 °C)
Fine vacuum phase:	90.8 h (120 °C)	556.7 h (120 °C)
Wall heating phase:	128.3 h (120 °C)	81.2 h (120 °C)
End vacuum:	0.001 mbar	0.001 mbar
Total drying time:	128.3 h	81.2 h

Table 1: Simulation of the transformer drying procedure with test sample 1 and test sample 2.

5.2 Mechanical endurance test (incl. sequence test)

Number of operations: 300,000 operations performed at oil temperature ≥ 75 °C,
200,000 operations performed at oil temperature < 75 °C
(total number of operations: 500,000)

Test arrangement / conditions: See sub-clause 4.2.

Sequence test: 200 operations recorded and evaluated by a transient recorder. Switching steps see appendix, fig. 1 (test sample 1) and fig. 2 (test sample 2). The sequence tests with test sample 1 and test sample 2 were carried out with and without change-over selector snap switch, at the beginning of the mechanical endurance test and after 500,000 operations. The evaluation of switching times is shown in tables 2a/b (test sample 1, with and without change-over selector snap switch) and tables 3a/b (test sample 2, with and without change-over selector snap switch). All switching times were within their permissible range.

Timing oscillograms: Each 10 timing oscillograms (exemplary without activated snap switch) were taken at the start of the mechanical endurance test and at 500,000 operations (test sample 1 and test sample 2). Comparison of these timing oscillograms showed suitability for service (see figs. 3.1 to 3.20 and figs. 4.1 to 4.20).

Switching time[3]	Oscillogram timestep	Permissible limits (-25 … 105 °C)		Readings at the start of the test	Readings at 500,000 operations
oTS_cTS_60 [1]	t1 – t2 [2]	min	700 ms	778 ms	806 ms
		max	980 ms	896 ms	899 ms
oTS_cTS_75 [1]		min	950 ms	1051 ms	1065 ms
		max	1250 ms	1182 ms	1205 ms
oCOS_cCOS	t3 – t4 [2]	min	530 ms	617 ms	545 ms
		max	700 ms	629 ms	672 ms
oTS_oCOS	t1 – t3 [2]	min	80 ms	196 ms	195 ms
		max	n/a	227 ms	216 ms
cCOS_cTS	t4 – t2 [2]	min	150 ms	292 ms	207 ms
		max	n/a	341 ms	359 ms
cPS_oCOS	t5 – t3 [2]	min	10 ms	42 ms	36 ms
		max	n/a	54 ms	50 ms
cCOS_oPS	t4 – t6 [2]	min	10 ms	195 ms	178 ms
		max	n/a	219 ms	283 ms

Table 2a: Mechanical endurance test – Evaluation of switching times of test sample 1 (change-over selector without snap switch).

Switching time[3]	Oscillogram timestep	Permissible limits (-25 … 105 °C)		Readings at the start of the test	Readings at 500,000 operations
oTS_cTS_60 [1]	- [2]	min	700 ms	786 ms	801 ms
		max	980 ms	889 ms	890 ms
oTS_cTS_75 [1]		min	950 ms	1068 ms	1061 ms
		max	1250 ms	1174 ms	1189 ms
oCOS_cCOS	- [2]	min	150 ms	237 ms	219 ms
		max	300 ms	255 ms	249 ms
oTS_oCOS	- [2]	min	350 ms	469 ms	484 ms
		max	n/a	492 ms	506 ms
cCOS_cTS	- [2]	min	300 ms	384 ms	352 ms
		max	n/a	447 ms	432 ms
cPS_oCOS	- [2]	min	10 ms	316 ms	322 ms
		max	n/a	330 ms	338 ms
cCOS_oPS	- [2]	min	10 ms	286 ms	298 ms
		max	n/a	322 ms	335 ms

Table 2b: Mechanical endurance test – Evaluation of switching times of test sample 1 (change-over selector with snap switch).

Switching time[3]	Oscillogram timestep	Permissible limits (-25 … 105 °C)		Readings at the start of the test	Readings at 500,000 operations
oTS_cTS_30 [1]	t1 – t2 [2]	min	250 ms	326 ms	341 ms
		max	500 ms	427 ms	435 ms
oTS_cTS_75 [1]		min	1200 ms	1319 ms	1305 ms
		max	1500 ms	1387 ms	1429 ms
oCOS_cCOS	t3 – t4 [2]	min	720 ms	817 ms	821 ms
		max	950 ms	872 ms	888 ms
oTS_oCOS	t1 – t3 [2]	min	120 ms	199 ms	193 ms
		max	n/a	220 ms	223 ms
cCOS_cTS	t4 – t2 [2]	min	200 ms	263 ms	243 ms
		max	n/a	305 ms	298 ms
cPS_oCOS	t5 – t3 [2]	min	10 ms	99 ms	89 ms
		max	n/a	134 ms	125 ms
cCOS_oPS	t4 – t6 [2]	min	10 ms	233 ms	221 ms
		max	n/a	270 ms	267 ms

Table 3a: Mechanical endurance test – Evaluation of switching times of test sample 2 (change-over selector without snap switch).

Switching time[3]	Oscillogram timestep	Permissible limits (-25 … 105 °C)		Readings at the start of the test	Readings at 500,000 operations
oTS_cTS_30 [1]	- [2]	min	250 ms	323 ms	324 ms
		max	500 ms	423 ms	429 ms
oTS_cTS_75 [1]		min	1200 ms	1318 ms	1301 ms
		max	1500 ms	1393 ms	1423 ms
oCOS_cCOS	- [2]	min	250 ms	283 ms	275 ms
		max	370 ms	313 ms	342 ms
oTS_oCOS	- [2]	min	480 ms	564 ms	597 ms
		max	n/a	592 ms	518 ms
cCOS_cTS	- [2]	min	350 ms	443 ms	454 ms
		max	n/a	473 ms	480 ms
cPS_oCOS	- [2]	min	10 ms	457 ms	430 ms
		max	n/a	504 ms	496 ms
cCOS_oPS	- [2]	min	10 ms	416 ms	427 ms
		max	n/a	437 ms	461 ms

Table 3b: Mechanical endurance test – Evaluation of switching times of test sample 2 (change-over selector with snap switch).

[1] Depending on the switching step of the tap selector following switching times can occur:
- test sample 1 (tap selector with 10 pitch design): oTSc_TS_60 or oTS_cTS_75
- test sample 2 (tap selector with 18 pitch design): oTSc_TS_30 or oTS_cTS_75

[2] Timesteps are exemplary marked in figures 3.1 and 4.1 (operations recorded without activated change-over selector snap switch).

[3] Declaration of symbols:

oTS:	Tap selector opens	oCOS:	Change-over selector opens	30:	30° switching step
cTS:	Tap selector closes	cCOS:	Change-over-selector closes	60:	60° switching step
oPS:	Potential switch opens	cPS:	Potential switch closes	75:	75° switching step

5.3 Operation test at 105 °C

Number of operations: 200 operations

Test arrangement / conditions: See sub-clause 4.3.

Sequence test: 200 operations recorded and evaluated by a transient recorder. Switching steps see appendix, fig. 1 (test sample 1) and fig. 2 (test sample 2). The sequence tests with test sample 1 and test sample 2 were carried out with and without change-over selector snap switch. The evaluation of switching times is shown in tables 4a/b (test sample 1, with and without change-over selector snap switch) and tables 5a/b (test sample 2, with and without change-over selector snap switch). All switching times were within their permissible range.

Timing oscillograms: Timing oscillograms (exemplary without activated snap switch) were taken at the start and at the end of the operation test (test sample 1 and test sample 2). Comparison of these timing oscillograms showed no significant difference (see figs. 5.1 to 5.10 and figs. 6.1 to 6.10).

Switching time[3]	Oscillogram timestep	Permissible limits (-25 … 105 °C)		Readings at the operation test at 105°C
oTS_cTS_60 [1]	t1 – t2 [2]	min	700 ms	745 ms
		max	980 ms	904 ms
oTS_cTS_75 [1]		min	950 ms	1021 ms
		max	1250 ms	1201 ms
oCOS_cCOS	t3 – t4 [2]	min	530 ms	605 ms
		max	700 ms	630 ms
oTS_oCOS	t1 – t3 [2]	min	80 ms	137 ms
		max	n/a	213 ms
cCOS_cTS	t4 – t2 [2]	min	150 ms	259 ms
		max	n/a	360 ms
cPS_oCOS	t5 – t3 [2]	min	10 ms	35 ms
		max	n/a	48 ms
cCOS_oPS	t4 – t6 [2]	min	10 ms	211 ms
		max	n/a	244 ms

Table 4a: Operation test at 105 °C – Evaluation of switching times of test sample 1 (change-over selector without snap switch).

Switching time[3]	Oscillogram timestep	Permissible limits (-25 … 105 °C)		Readings at the operation test at 105°C
oTS_cTS_60 [1]	- [2]	min	700 ms	758 ms
		max	980 ms	940 ms
oTS_cTS_75 [1]		min	950 ms	1030 ms
		max	1250 ms	1210 ms
oCOS_cCOS	- [2]	min	150 ms	234 ms
		max	300 ms	283 ms
oTS_oCOS	- [2]	min	350 ms	476 ms
		max	n/a	493 ms
cCOS_cTS	- [2]	min	300 ms	324 ms
		max	n/a	454 ms
cPS_oCOS	- [2]	min	10 ms	311 ms
		max	n/a	322 ms
cCOS_oPS	- [2]	min	10 ms	283 ms
		max	n/a	347 ms

Table 4b: Operation test at 105 °C – Evaluation of switching times of test sample 1 (change-over selector with snap switch).

Switching time[3]	Oscillogram timestep	Permissible limits (-25 … 105 °C)		Readings at the operation test at 105°C
oTS_cTS_30 [1]	t1 – t2 [2]	min	250 ms	326 ms
		max	500 ms	427 ms
oTS_cTS_75 [1]		min	1200 ms	1319 ms
		max	1500 ms	1387 ms
oCOS_cCOS	t3 – t4 [2]	min	720 ms	817 ms
		max	950 ms	872 ms
oTS_oCOS	t1 – t3 [2]	min	120 ms	199 ms
		max	n/a	220 ms
cCOS_cTS	t4 – t2 [2]	min	200 ms	263 ms
		max	n/a	305 ms
cPS_oCOS	t5 – t3 [2]	min	10 ms	99 ms
		max	n/a	134 ms
cCOS_oPS	t4 – t6 [2]	min	10 ms	233 ms
		max	n/a	270 ms

Table 5a: Operation test at 105 °C – Evaluation of switching times of test sample 2 (change-over selector without snap switch).

Switching time[3]	Oscillogram timestep	Permissible limits (-25 … 105 °C)		Readings at the operation test at 105°C
oTS_cTS_30 [1]	- [2]	min	250 ms	323 ms
		max	500 ms	414 ms
oTS_cTS_75 [1]		min	1200 ms	1297 ms
		max	1500 ms	1422 ms
oCOS_cCOS	- [2]	min	250 ms	278 ms
		max	370 ms	316 ms
oTS_oCOS	- [2]	min	480 ms	533 ms
		max	n/a	606 ms
cCOS_cTS	- [2]	min	350 ms	467 ms
		max	n/a	488 ms
cPS_oCOS	- [2]	min	10 ms	444 ms
		max	n/a	519 ms
cCOS_oPS	- [2]	min	10 ms	443 ms
		max	n/a	468 ms

Table 5b: Operation test at 105 °C – Evaluation of switching times of test sample 2 (change-over selector with snap switch).

[1] Depending on the switching step of the tap selector following switching times can occur:
- test sample 1 (tap selector with 10 pitch design): oTSc_TS_60 or oTS_cTS_75
- test sample 2 (tap selector with 18 pitch design): oTSc_TS_30 or oTS_cTS_75

[2] Timesteps are exemplary marked in figures 5.1 and 6.1 (operations recorded without activated change-over selector snap switch).

[3] Declaration of symbols:

oTS:	Tap selector opens	oCOS:	Change-over selector opens	30:	30° switching step
cTS:	Tap selector closes	cCOS:	Change-over-selector closes	60:	60° switching step
oPS:	Potential switch opens	cPS:	Potential switch closes	75:	75° switching step

6. Test results

The requirements according to IEC 60214-1:2014 “Tap-changers - Part 1: Performance requirements and test methods”, sub-clause 5.2.6: “Mechanical tests” were met.

The simulation of the transformer drying procedure was passed successfully.

At the start of the mechanical endurance test and at 500,000 operations each 200 operations were recorded and evaluated. Furthermore, each 10 timing oscillograms were taken at the start of the mechanical endurance test and at 500,000 operations. Comparison of these timing oscillograms showed suitability for service (see appendix, figs. 3.1 to 3.20 and figs. 4.1 to 4.20). All switching times were within their permissible range (see tables 2a/b and tables 3a/b).

During the operation test at 105 °C, 200 operations were recorded and evaluated. Furthermore, timing oscillograms were taken at the start and at the end of the operation test. Comparison of these timing oscillograms with those obtained at the start and the end of the mechanical endurance test showed suitability for service (see appendix, figs. 5.1 to 5.10 and figs. 6.1 to 6.10). All evaluated switching times were within their permissible range (see tables 4a/b and tables 5a/b).

During the performed tests, there were no failures or undue wear of the contacts or mechanical parts that would lead to mechanical failure if operation continued.

7. Appendix

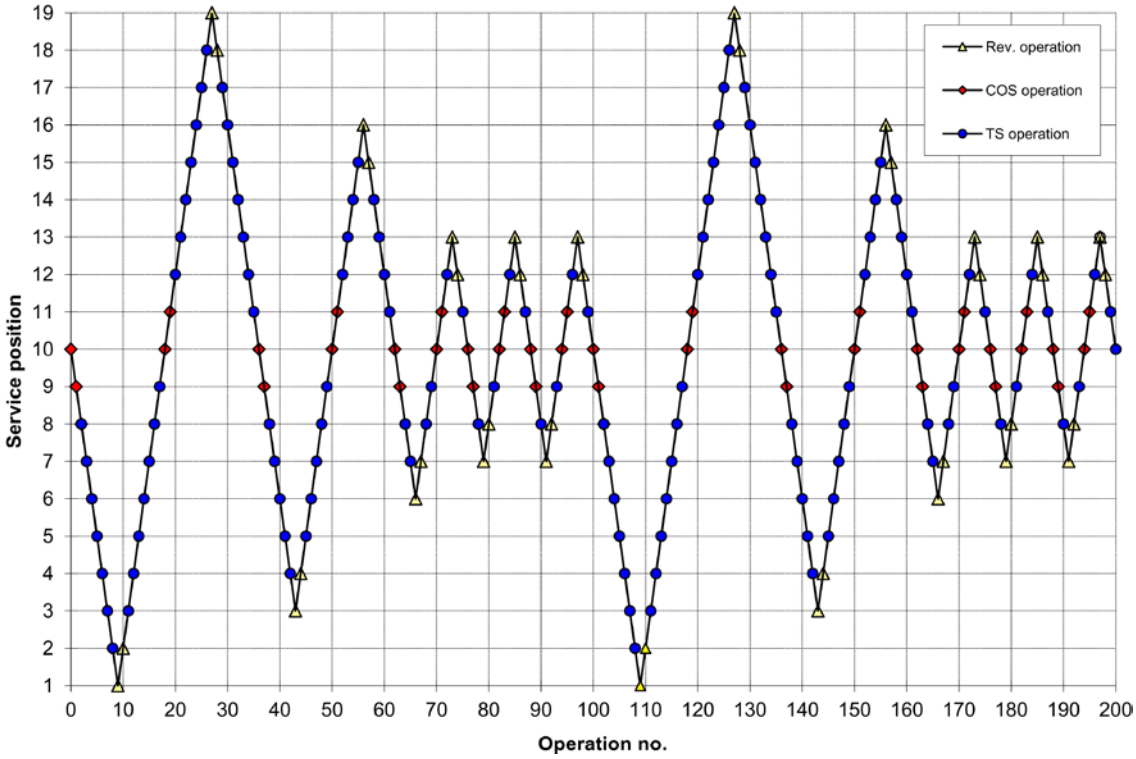

Fig. 1: Switching steps for a 10 pitch tap selector with change-over selector (test sample 1).

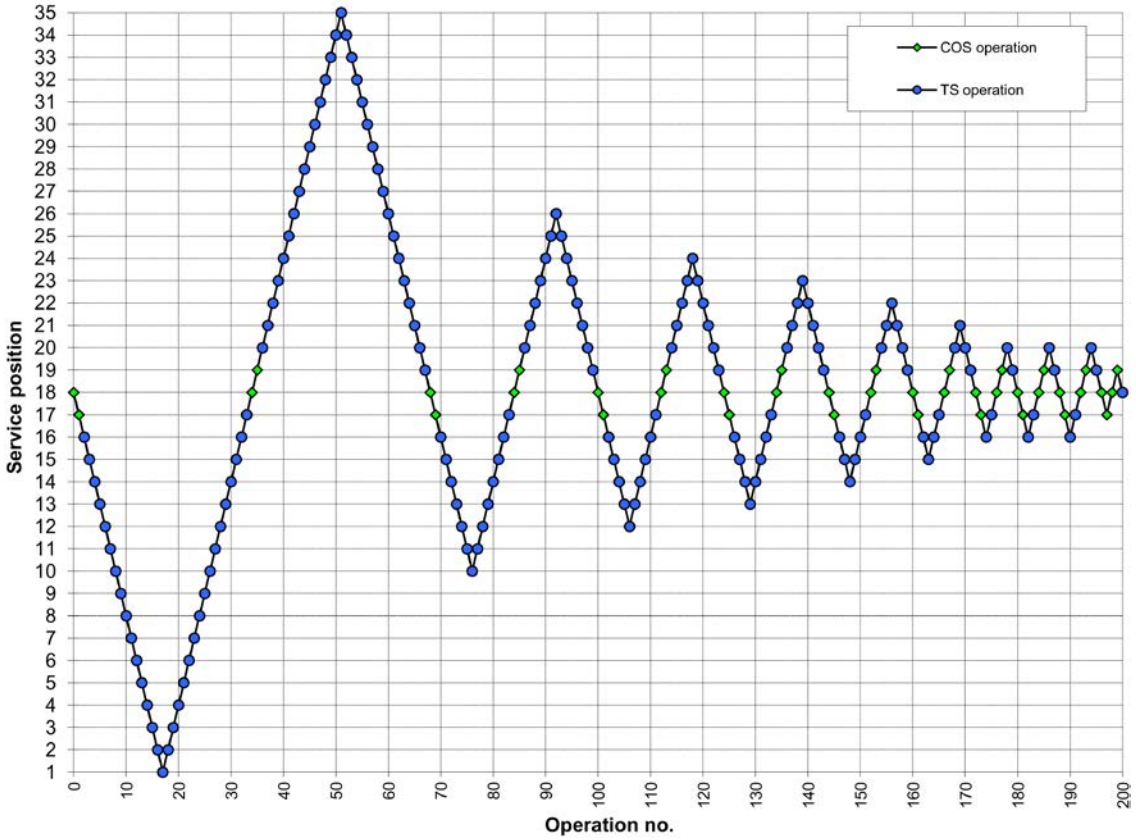

Fig. 2: Switching steps for a 18 pitch tap selector with change-over selector (test sample 2).

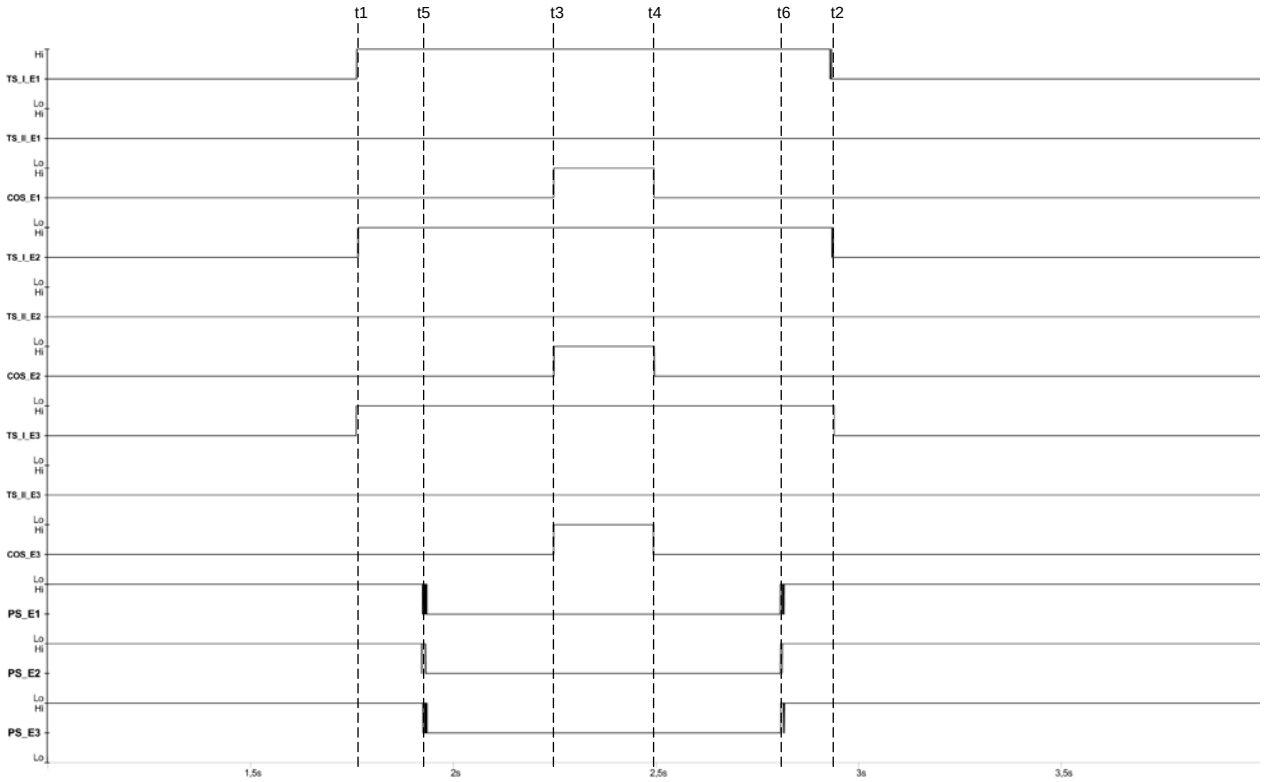

Fig. 3.1: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the beginning of the test.

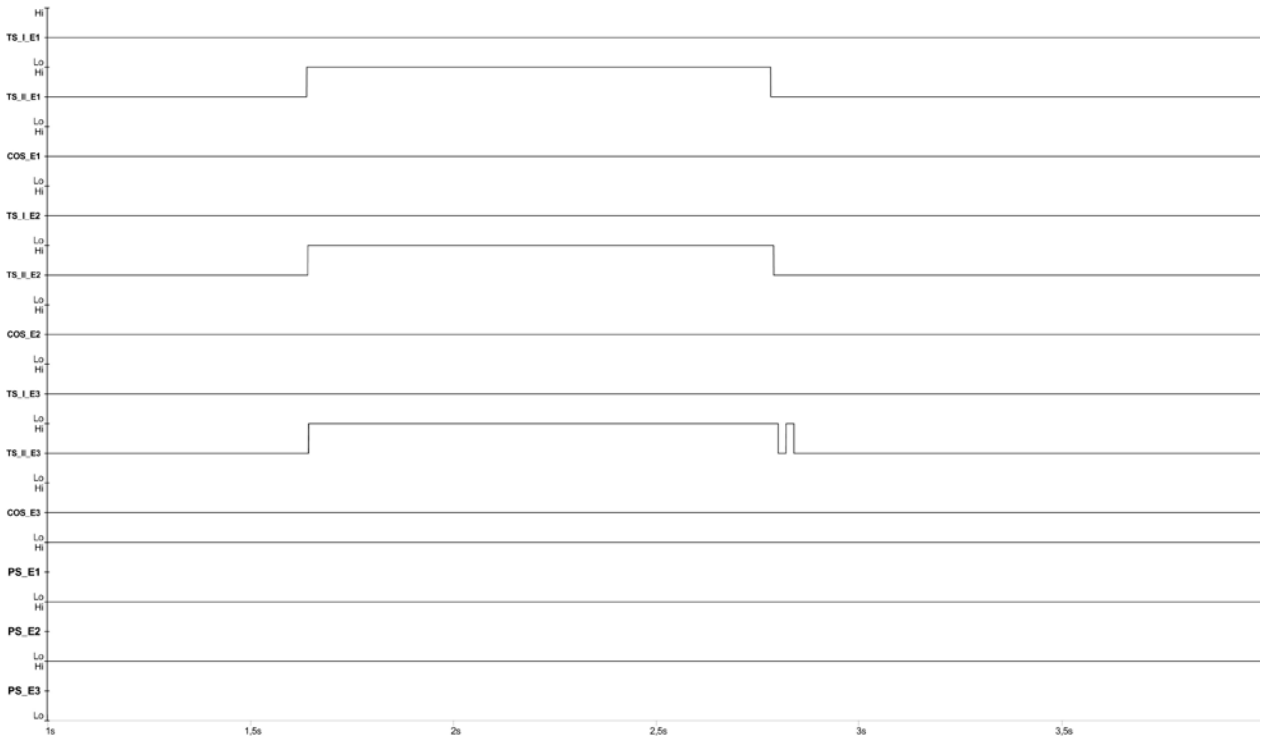

Fig. 3.2: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the beginning of the test.

TS_I, TS_II: Tap selector arm 1, 2
E1, E2, E3: Contact planes 1, 2, 3
COS: Change-over selector
PS: Potential switch

t1: Tap selector opens
t2: Tap selector closes
t3: Change-over selector opens
t4: Change-over selector closes
t5: Potential switch closes
t6: Potential switch opens

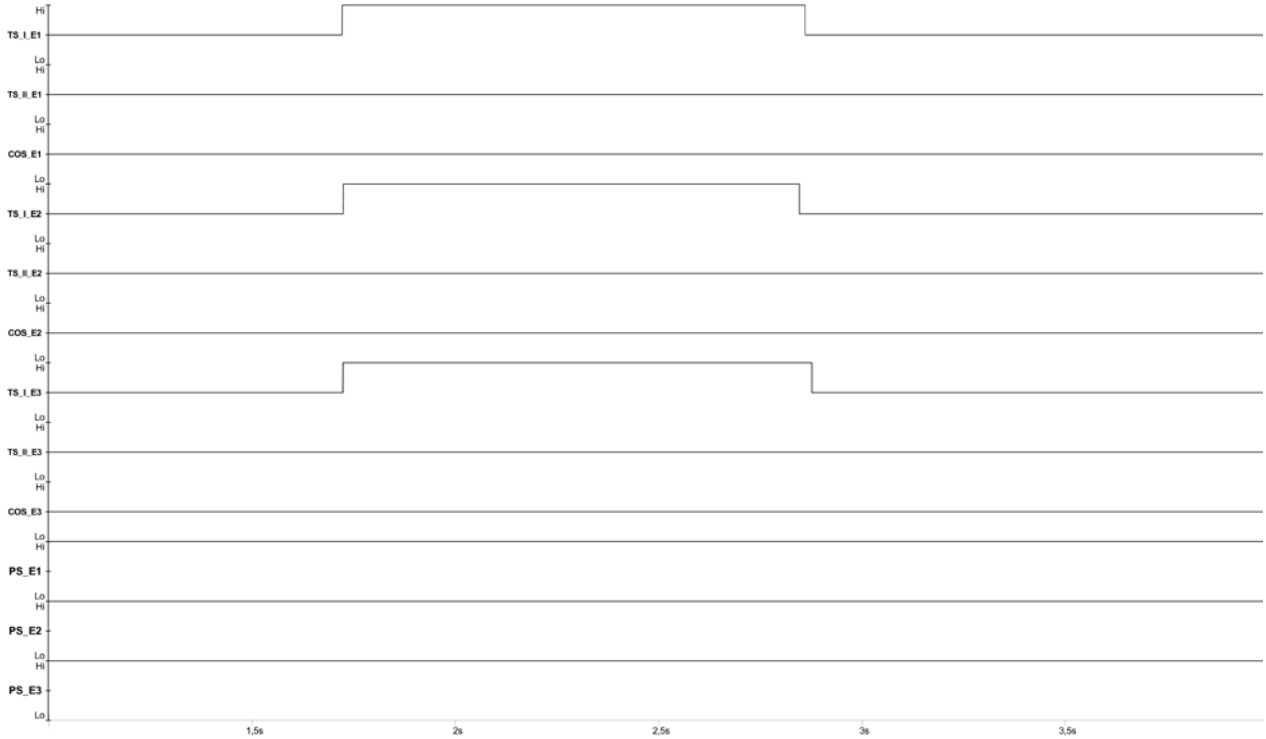

Fig. 3.3: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the beginning of the test.

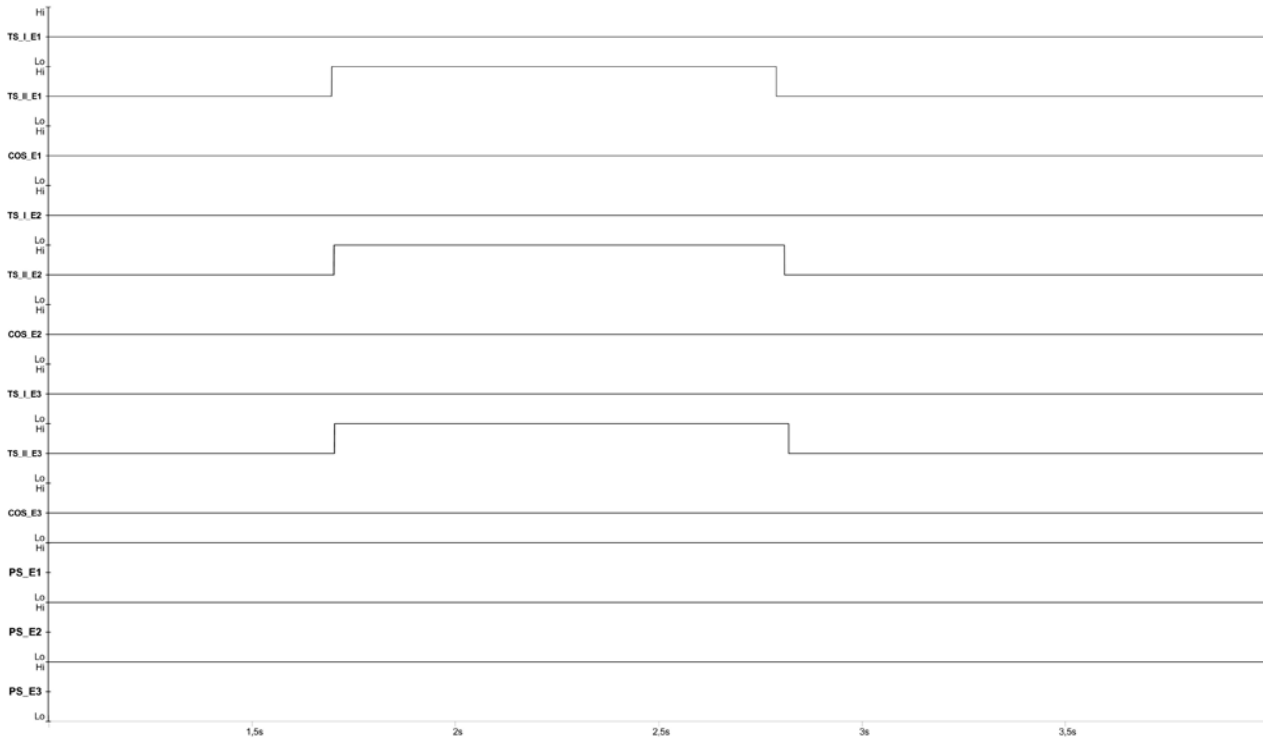

Fig. 3.4: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the beginning of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

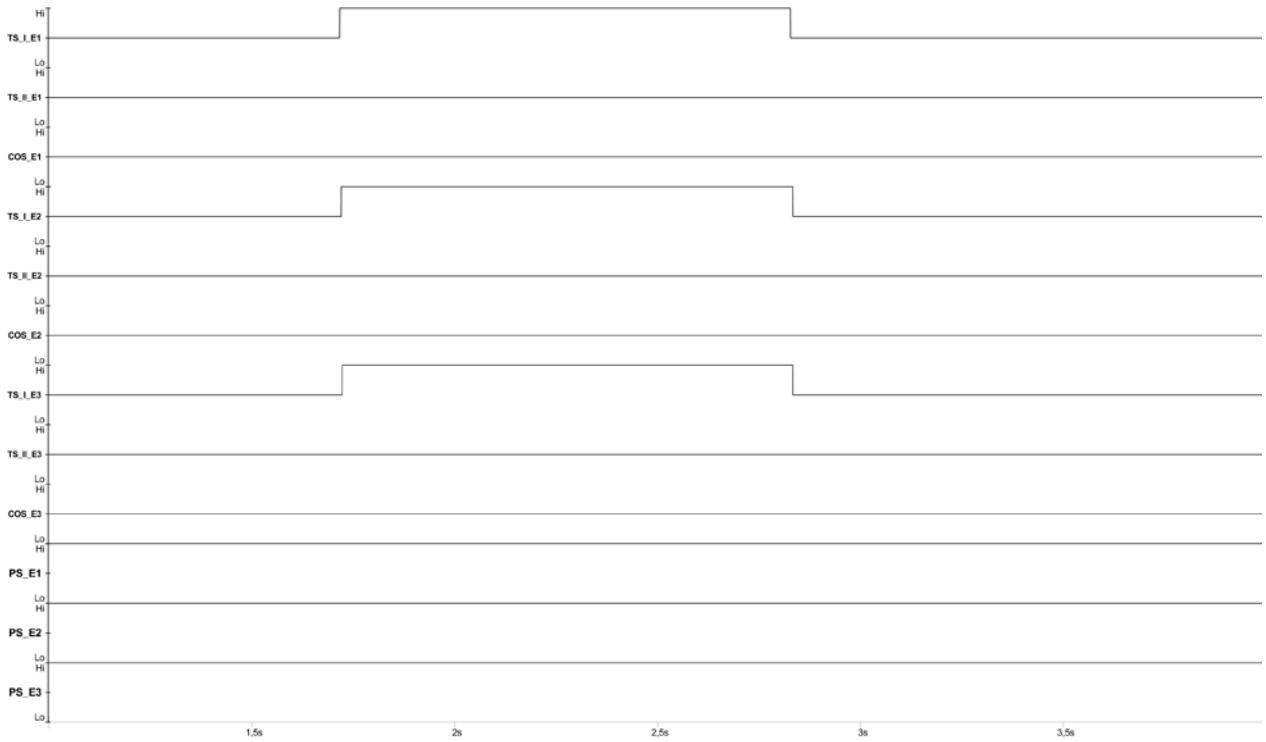

Fig. 3.5: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the beginning of the test.

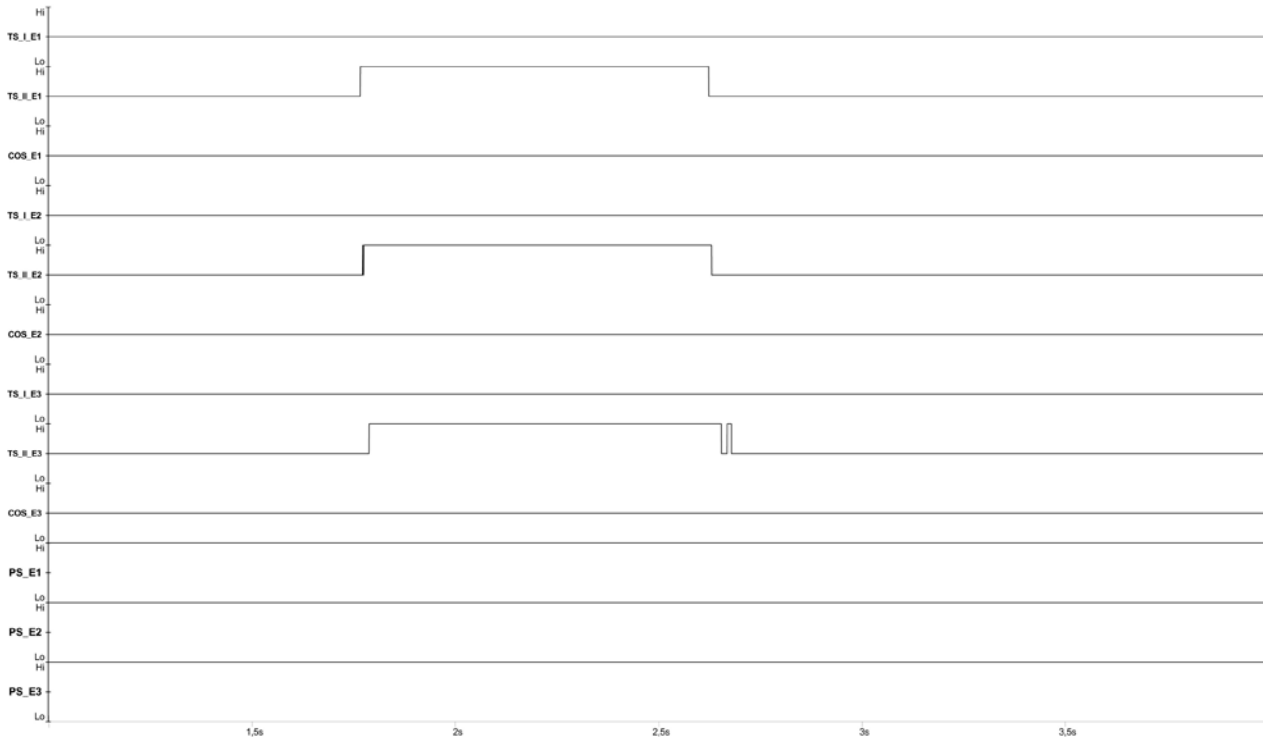

Fig. 3.6: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the beginning of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

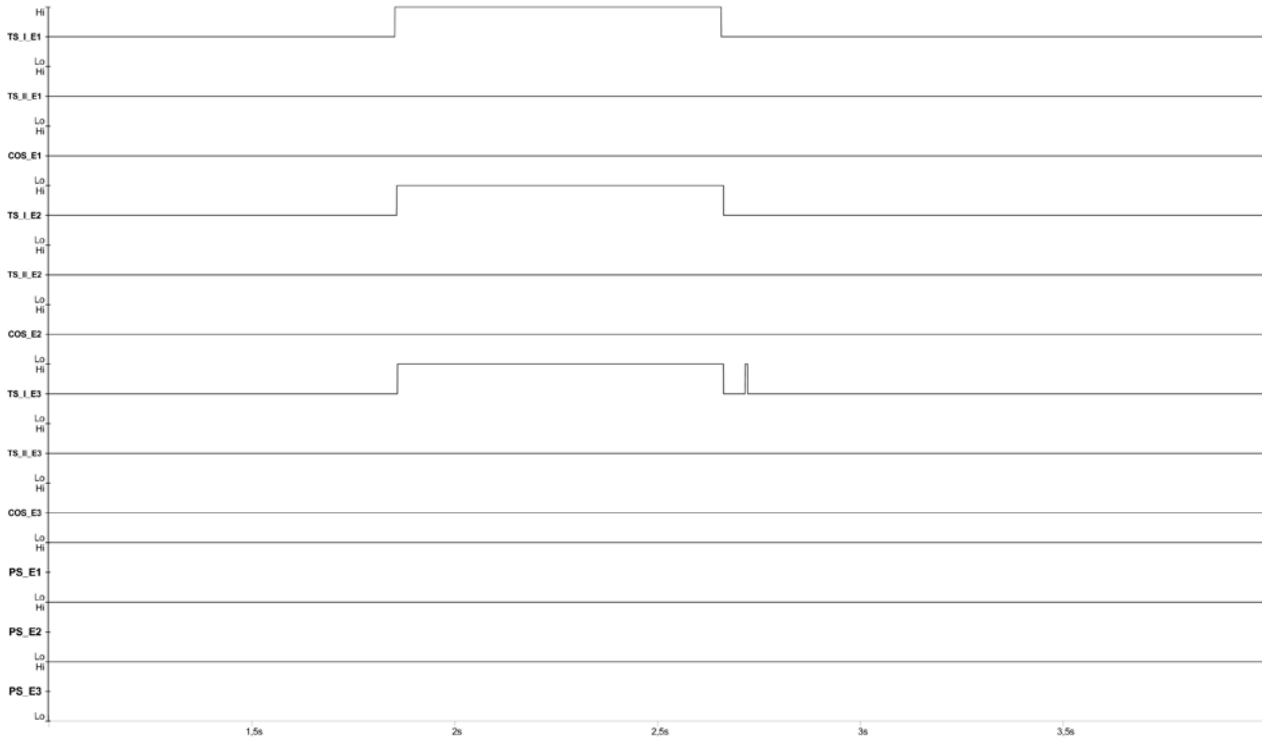

Fig. 3.7: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the beginning of the test.

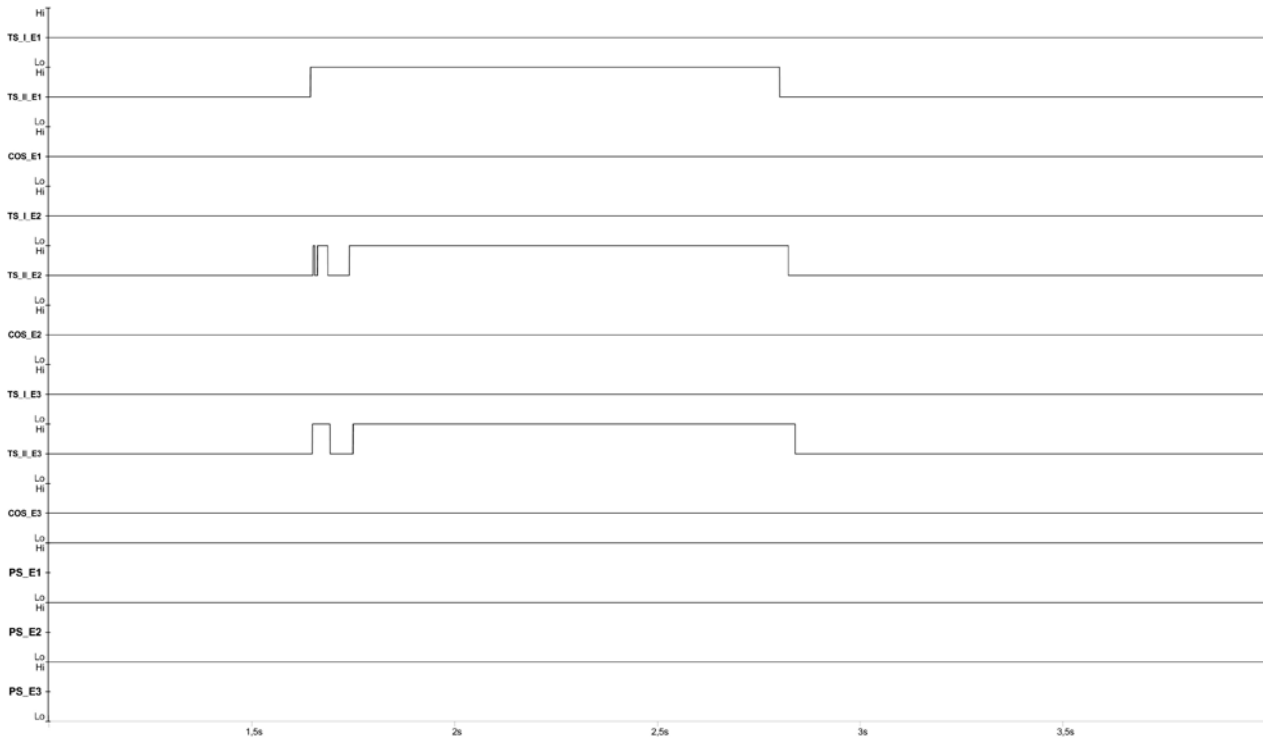

Fig. 3.8: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the beginning of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

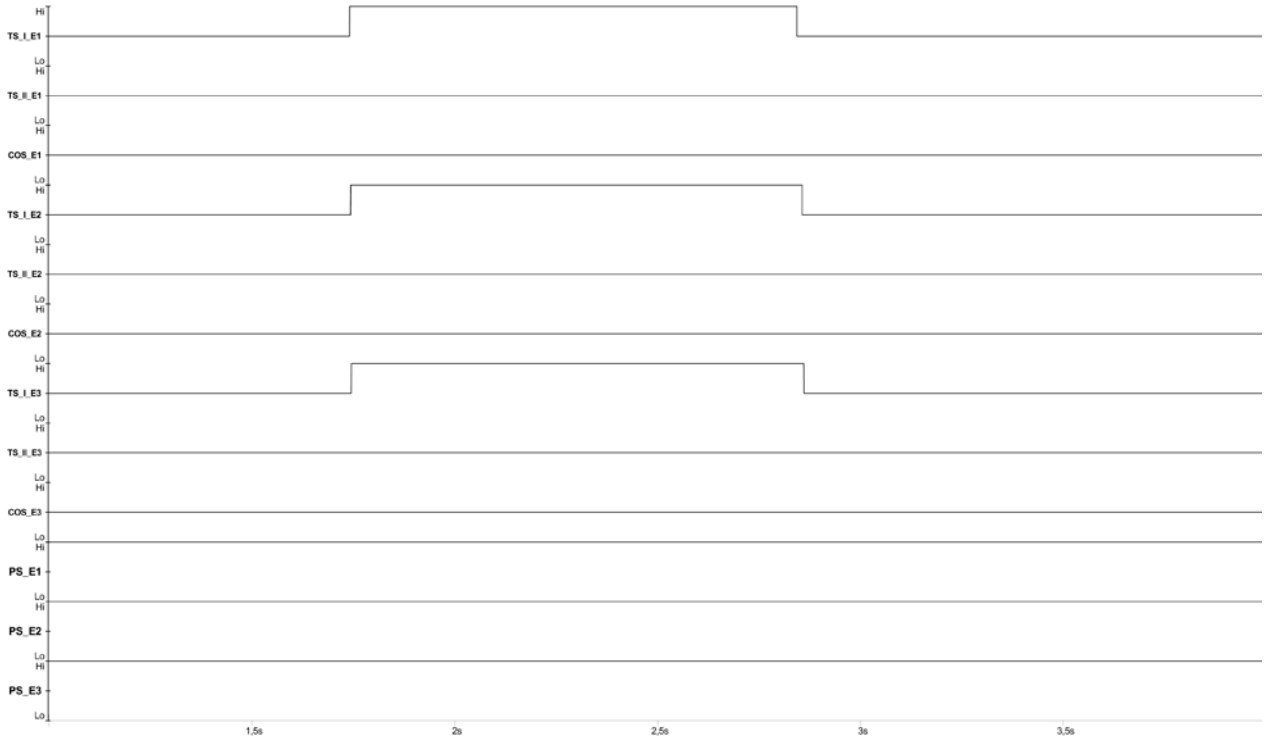

Fig. 3.9: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the beginning of the test.

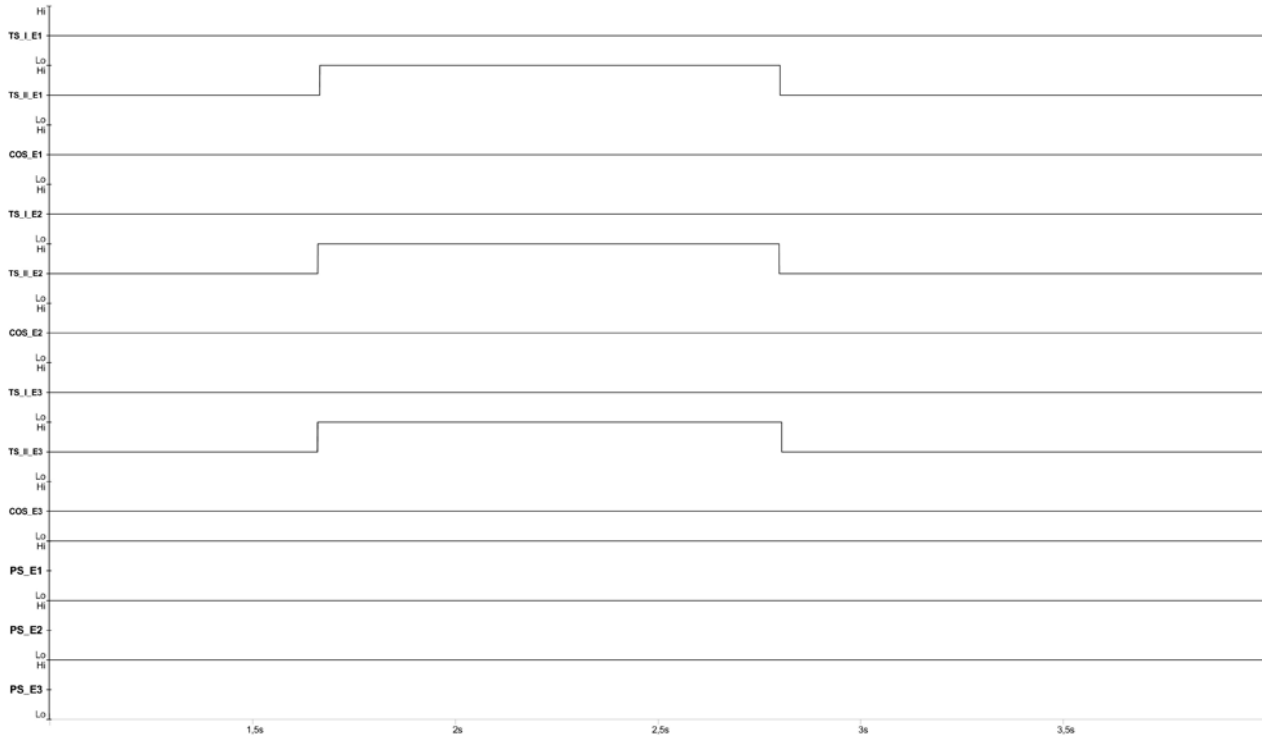

Fig. 3.10: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the beginning of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

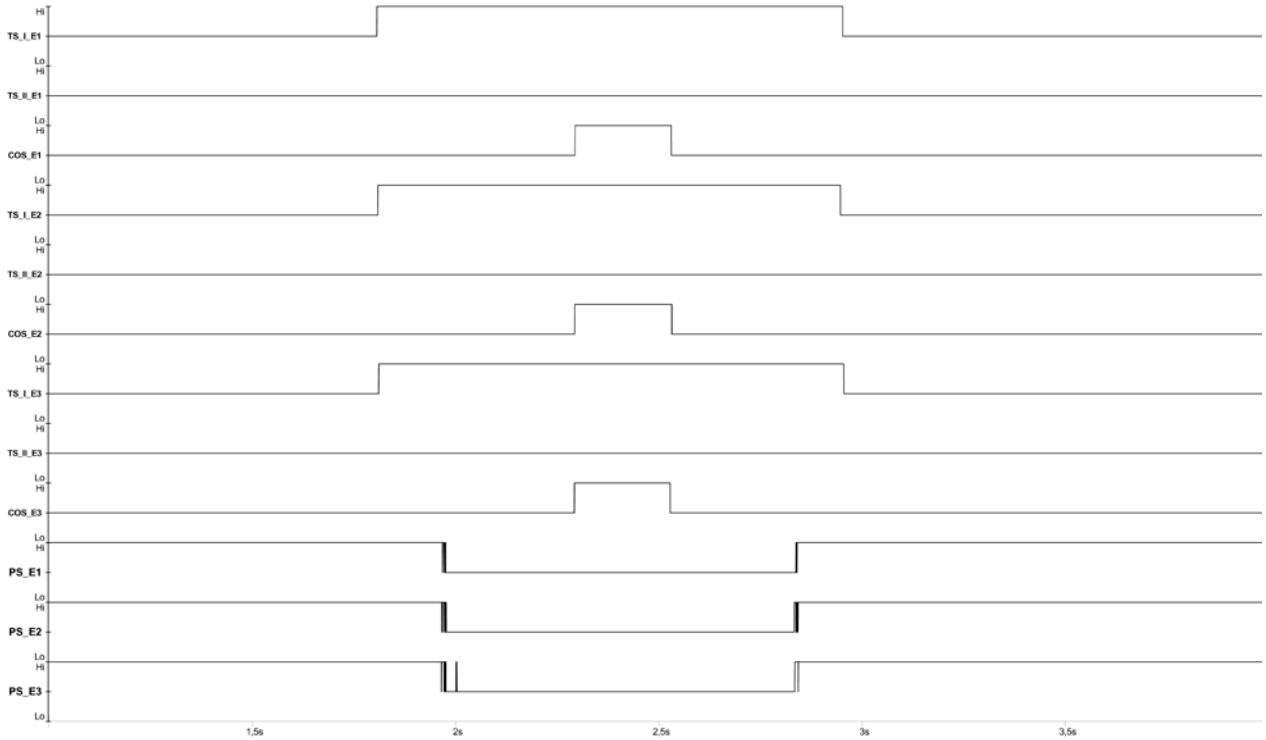

Fig. 3.11: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the end of the test.

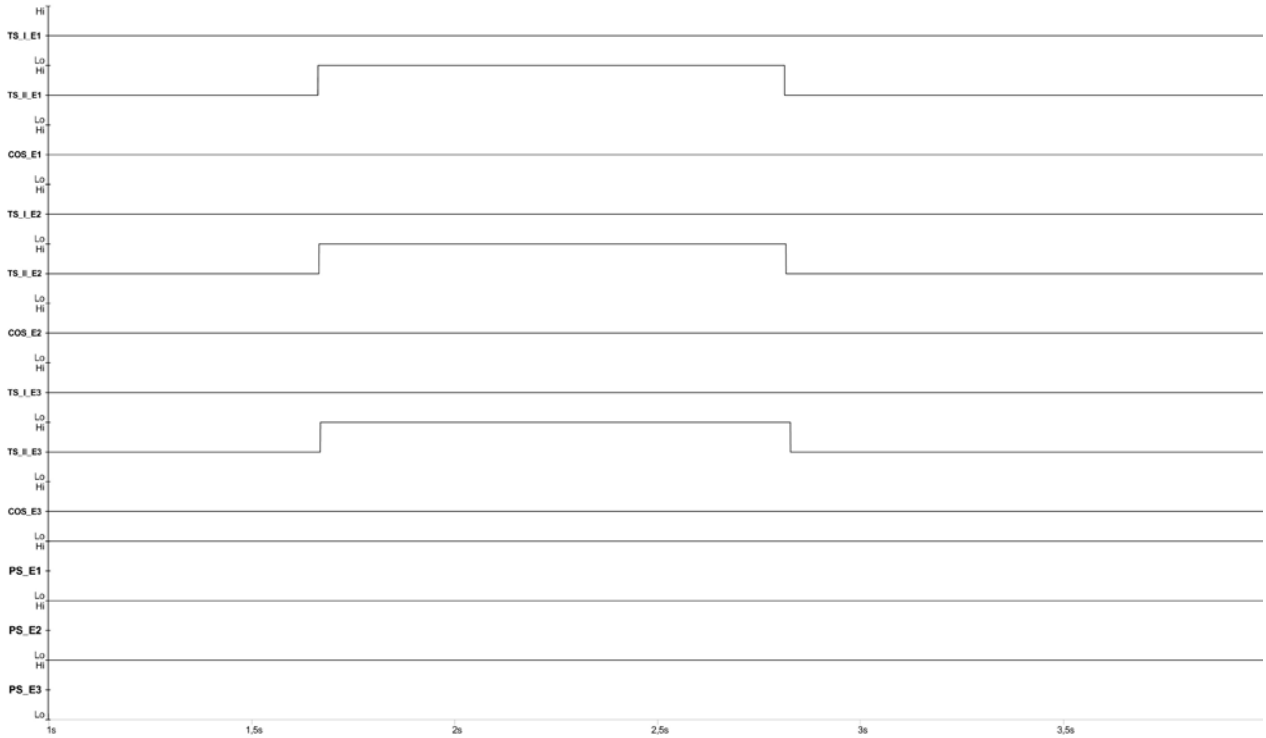

Fig. 3.12: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

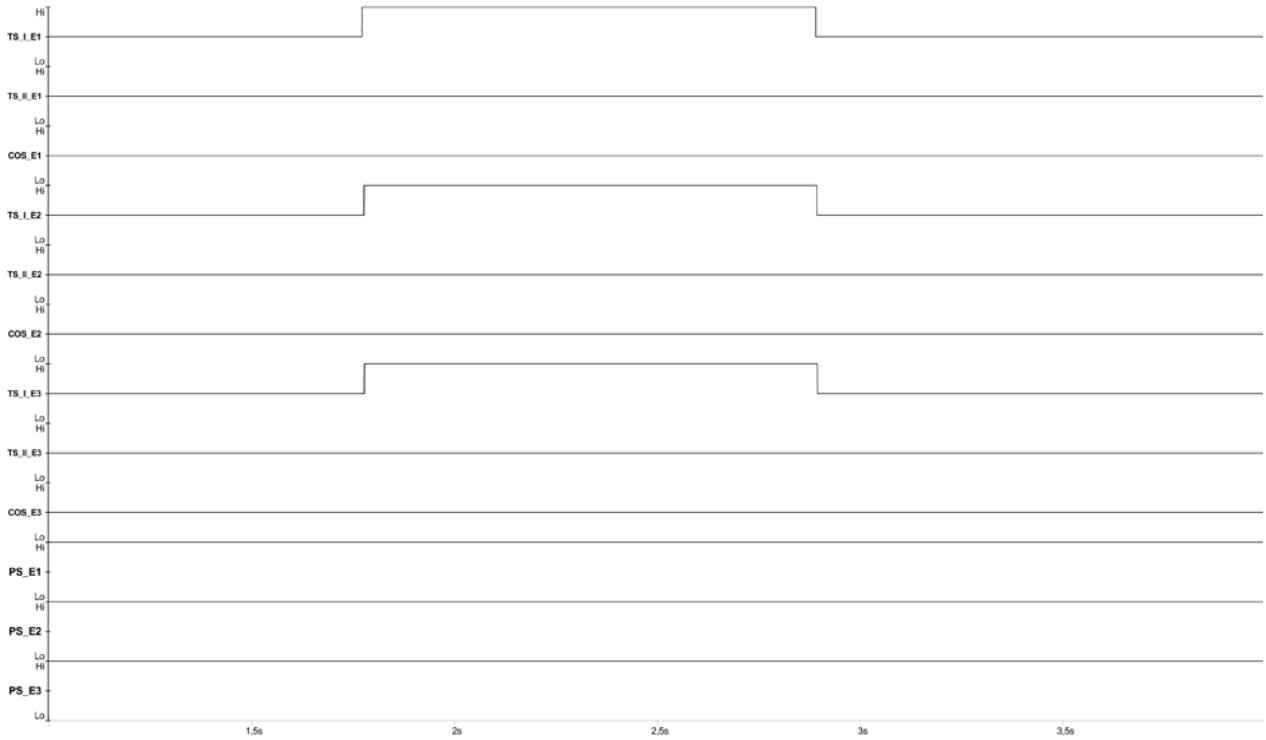

Fig. 3.13: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the end of the test.

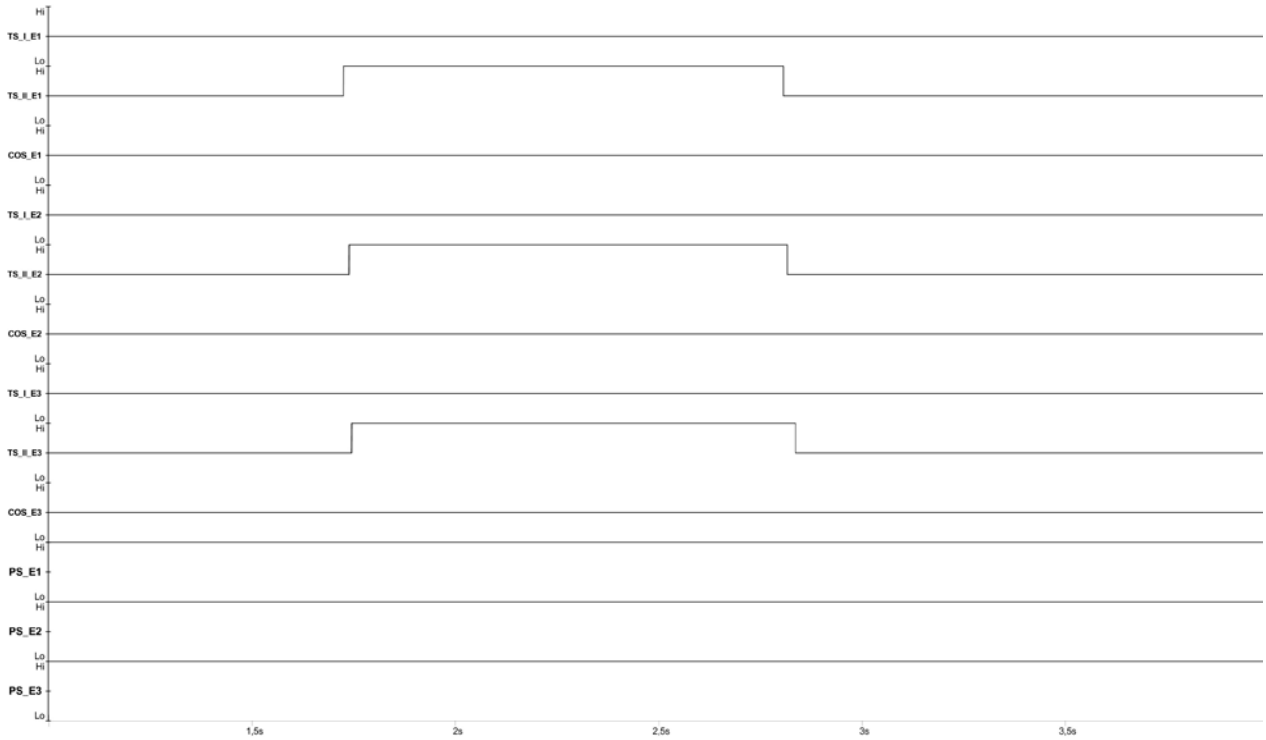

Fig. 3.14: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

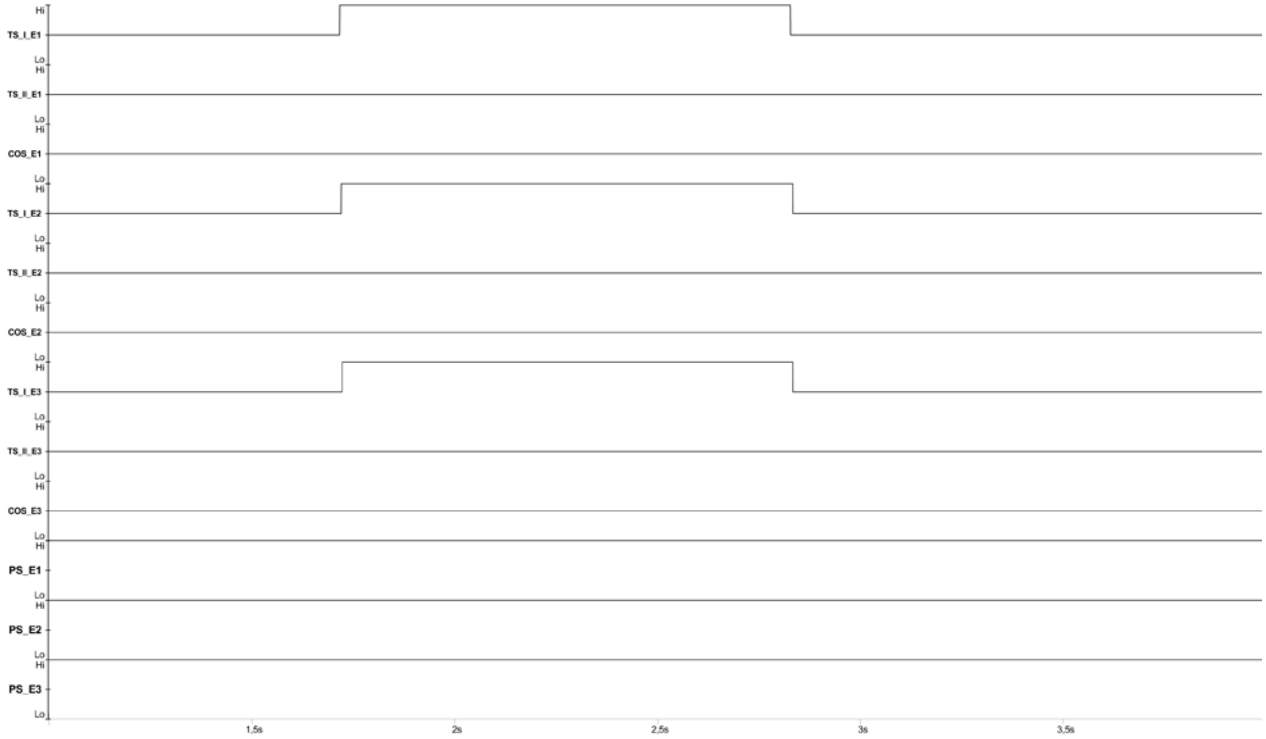

Fig. 3.15: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the end of the test.

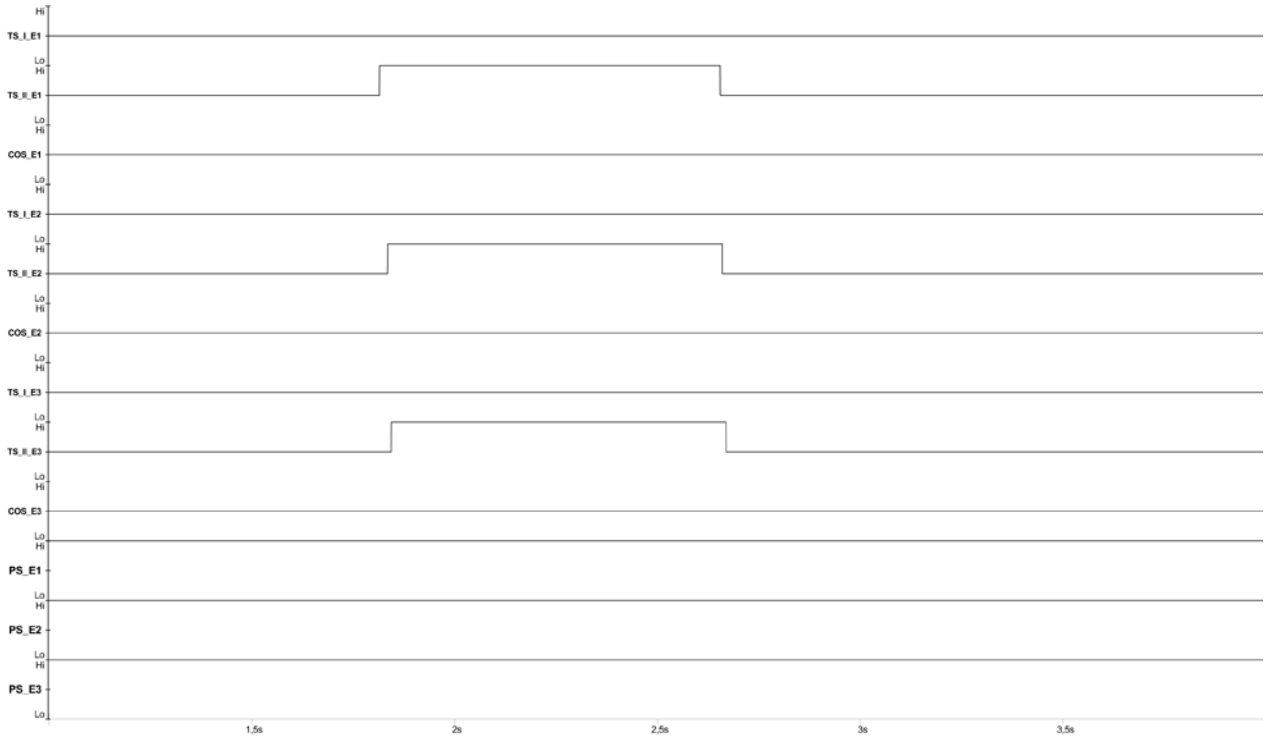

Fig. 3.16: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

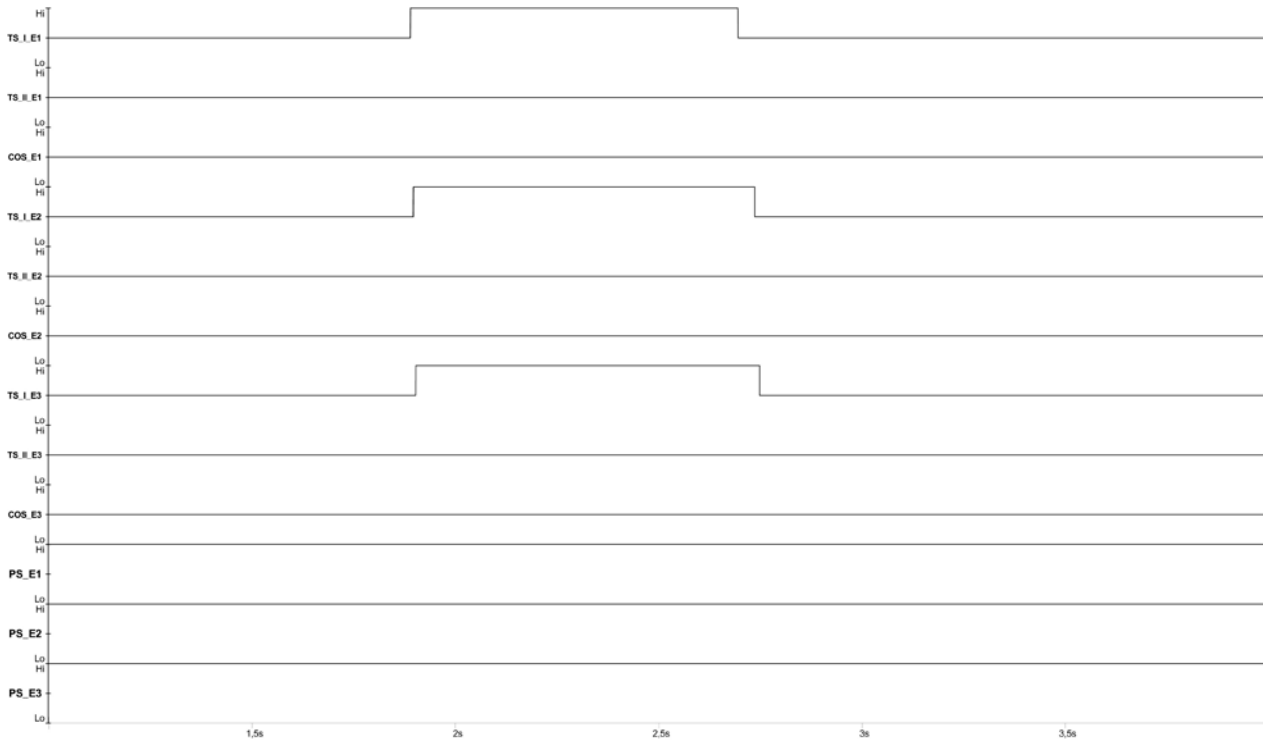

Fig. 3.17: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the end of the test.

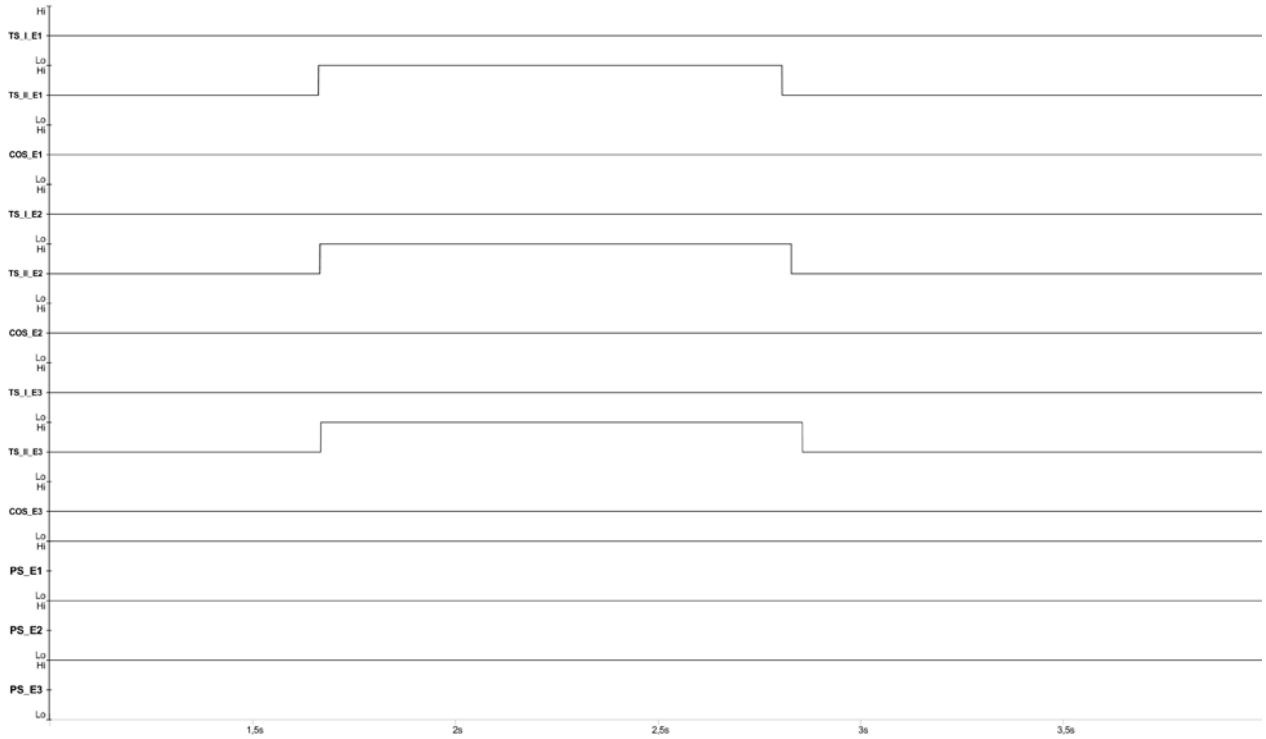

Fig. 3.18: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

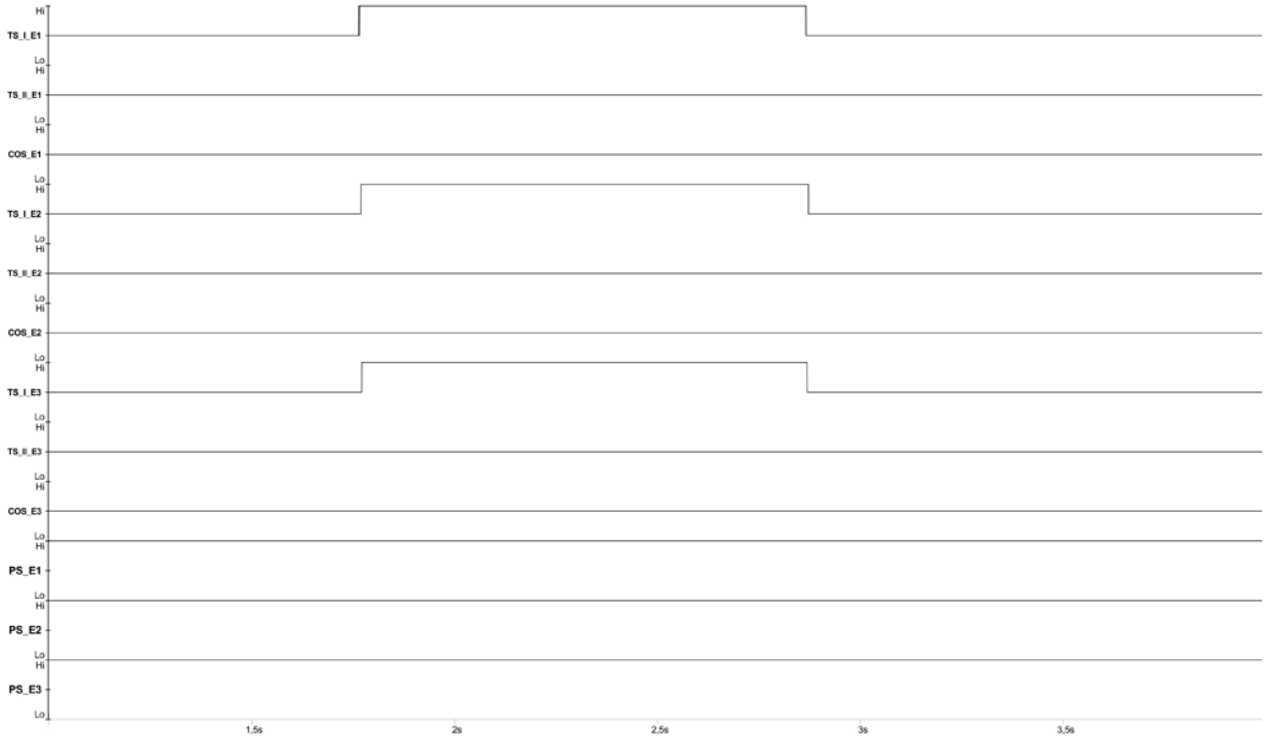

Fig. 3.19: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the end of the test.

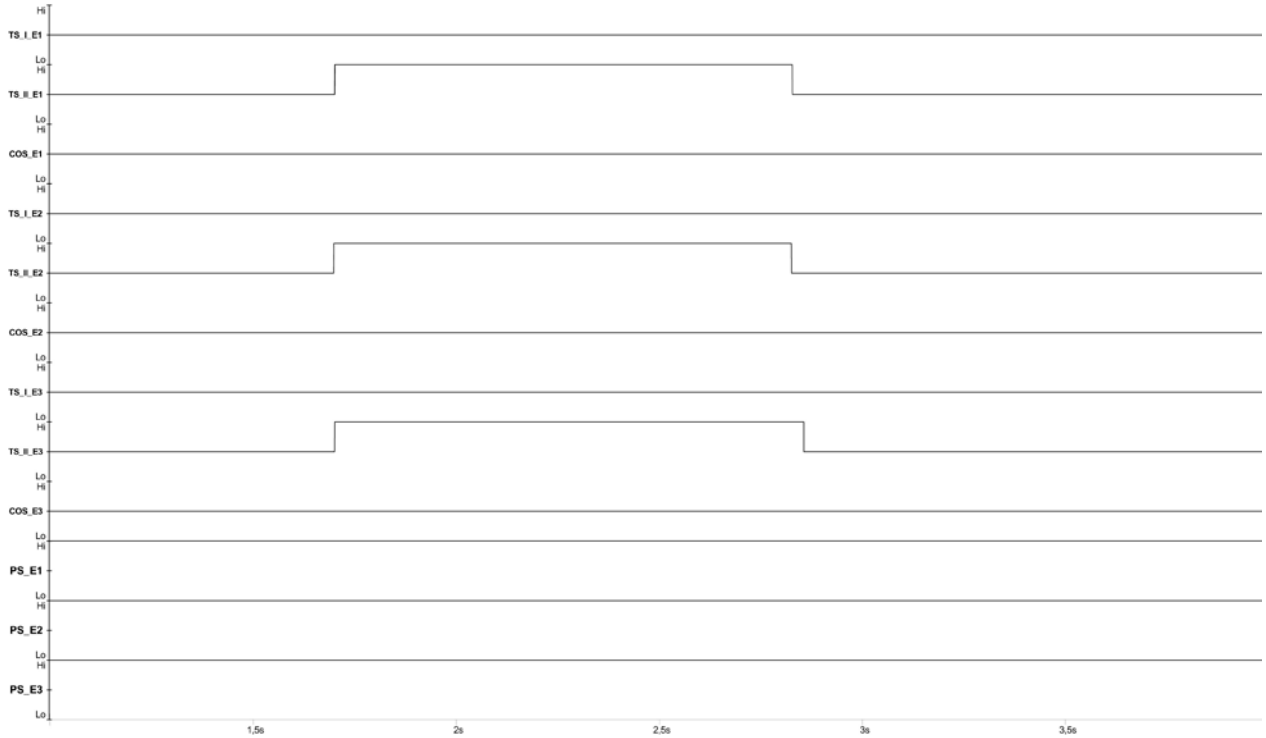

Fig. 3.20: Mechanical endurance test 500,000 operations (test sample 1) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

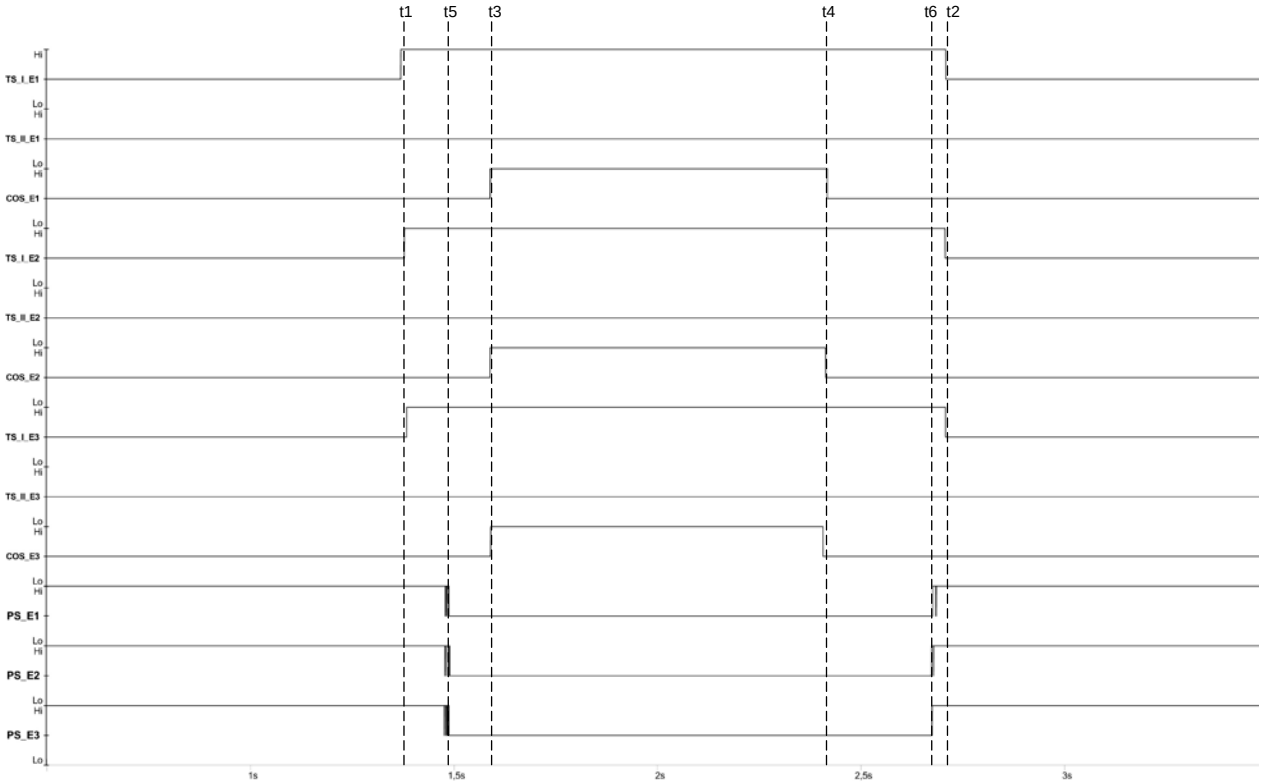

Fig. 4.1: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the beginning of the test.

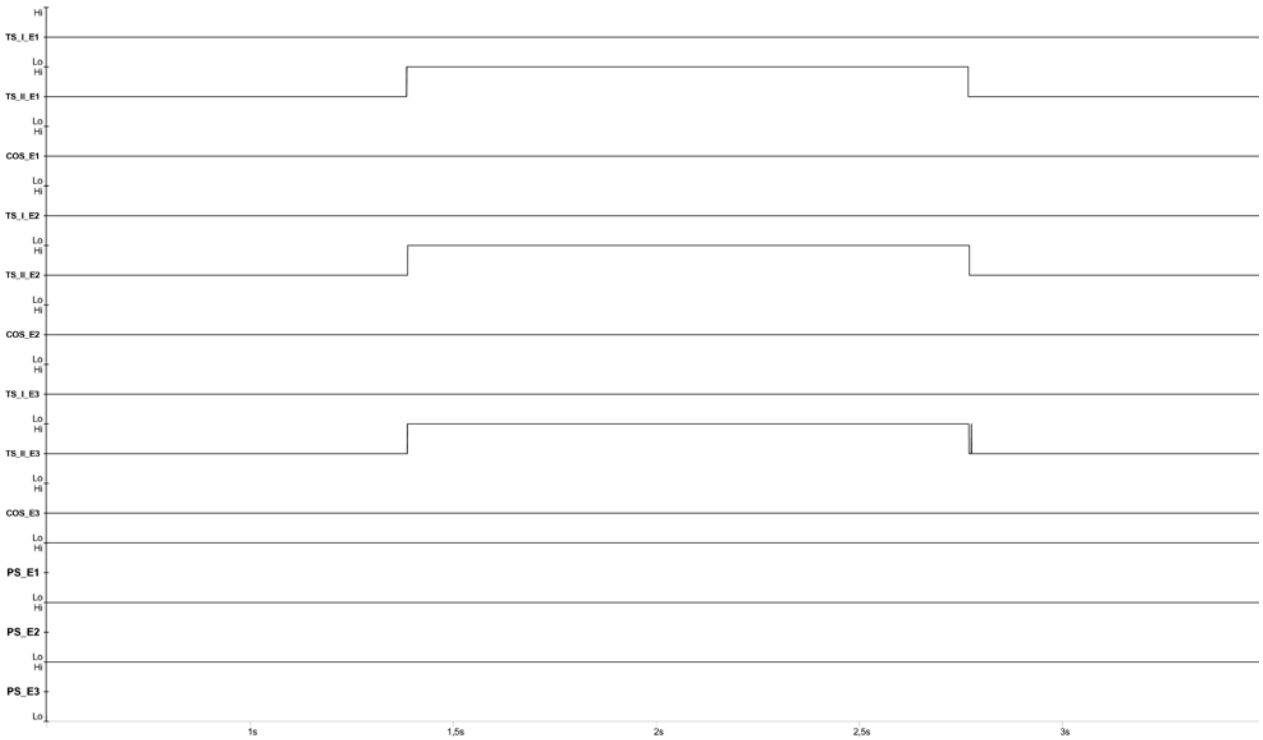

Fig. 4.2: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the beginning of the test.

TS_I, TS_II: Tap selector arm 1, 2
E1, E2, E3: Contact planes 1, 2, 3
COS: Change-over selector
PS: Potential switch

t1: Tap selector opens
t2: Tap selector closes
t3: Change-over selector opens
t4: Change-over selector closes
t5: Potential switch closes
t6: Potential switch opens

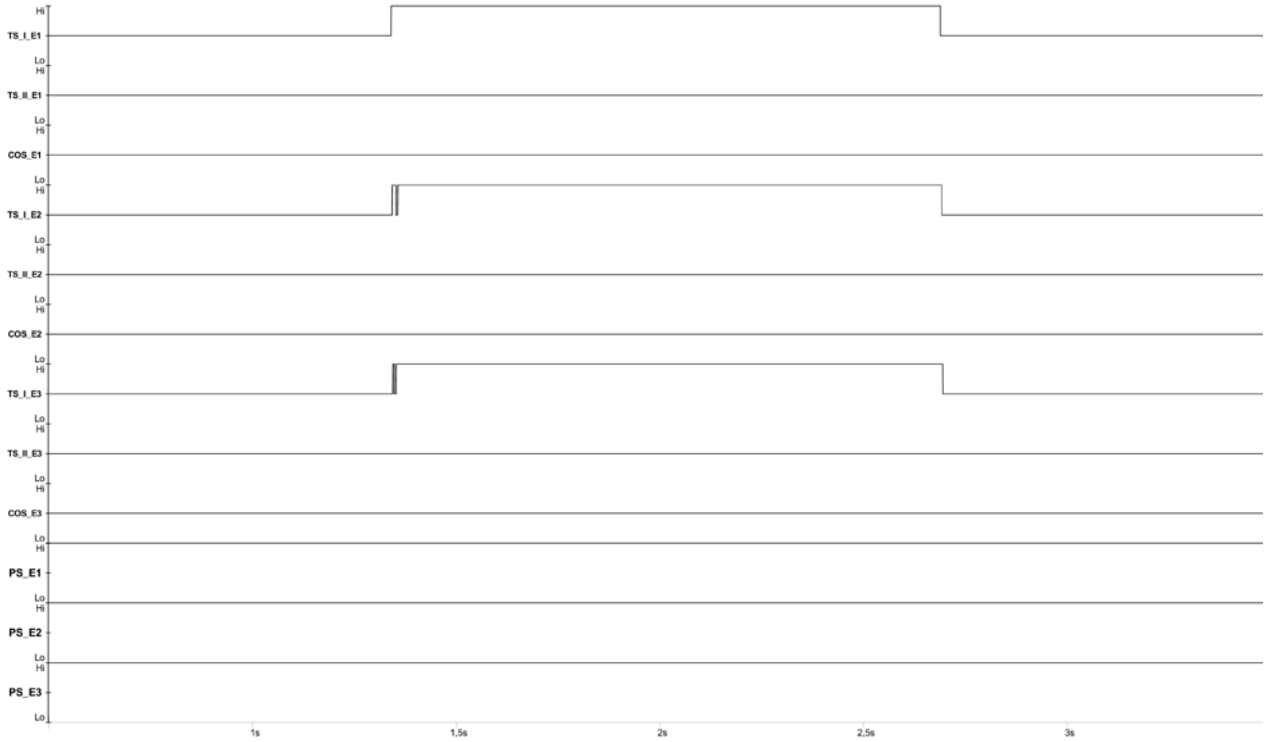

Fig. 4.3: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the beginning of the test.

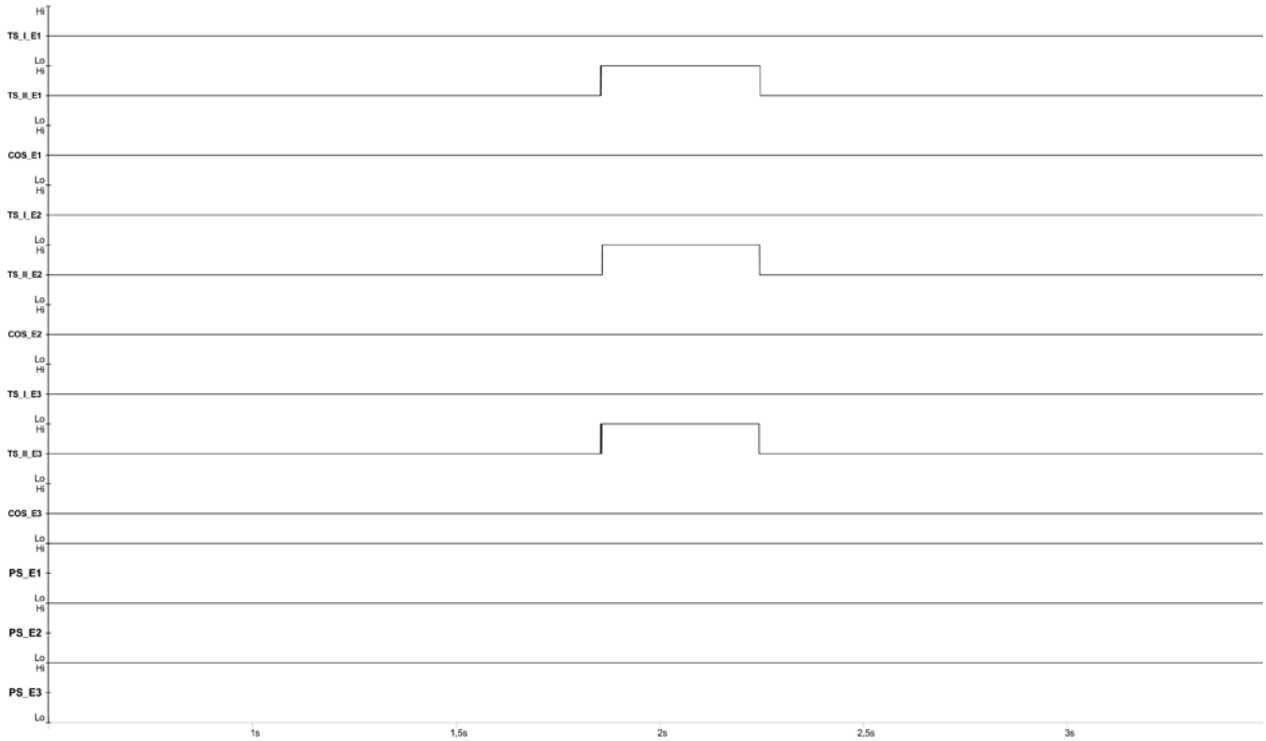

Fig. 4.4: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the beginning of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

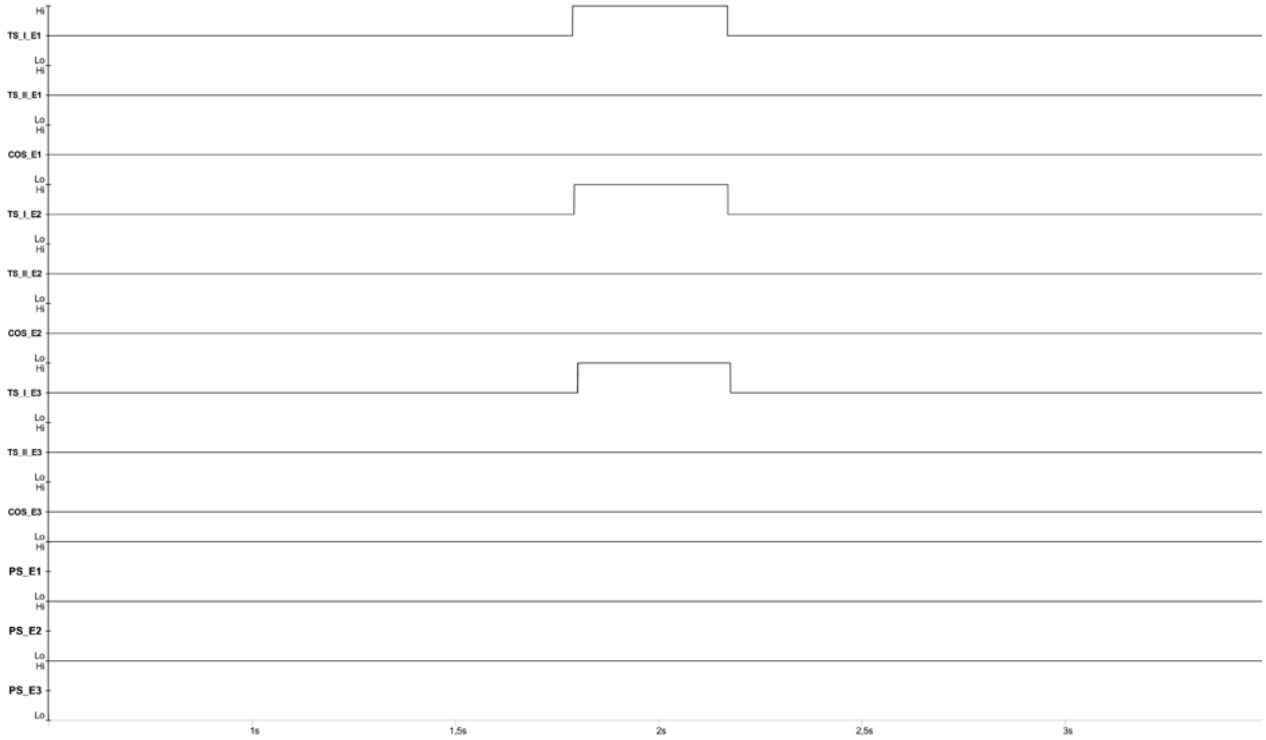

Fig. 4.5: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the beginning of the test.

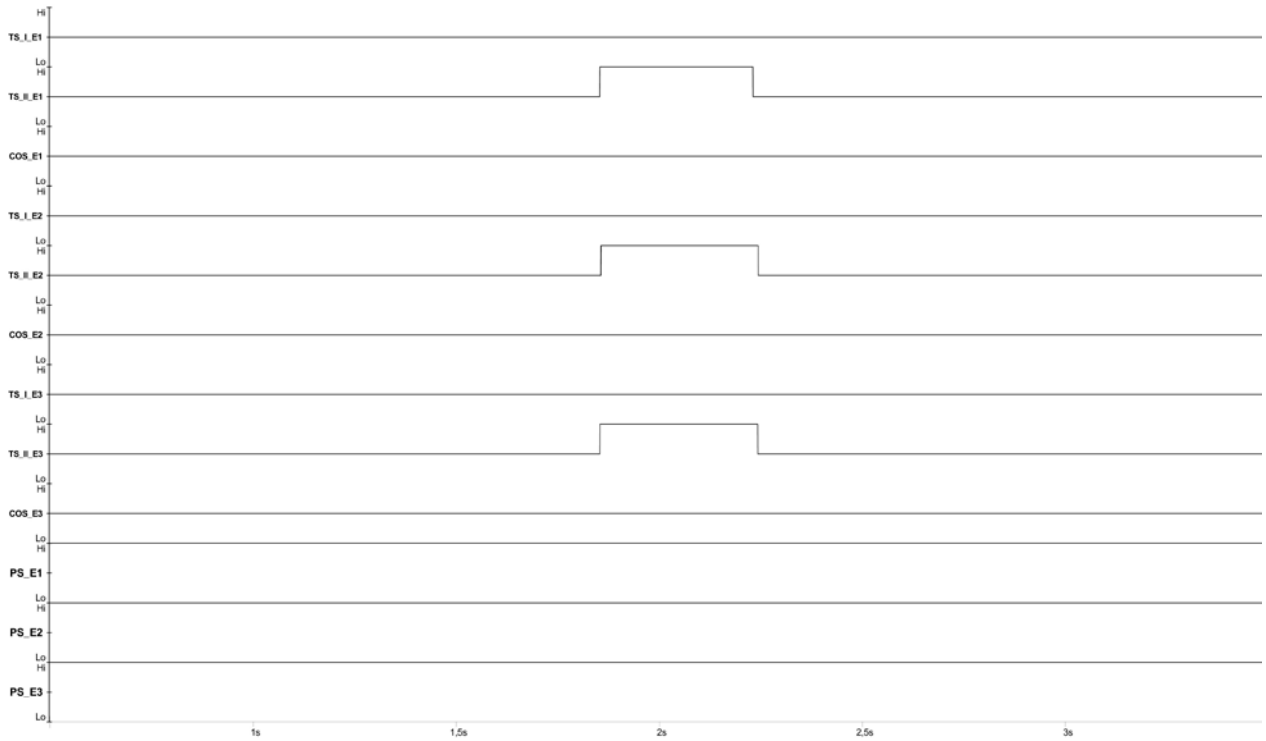

Fig. 4.6: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the beginning of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

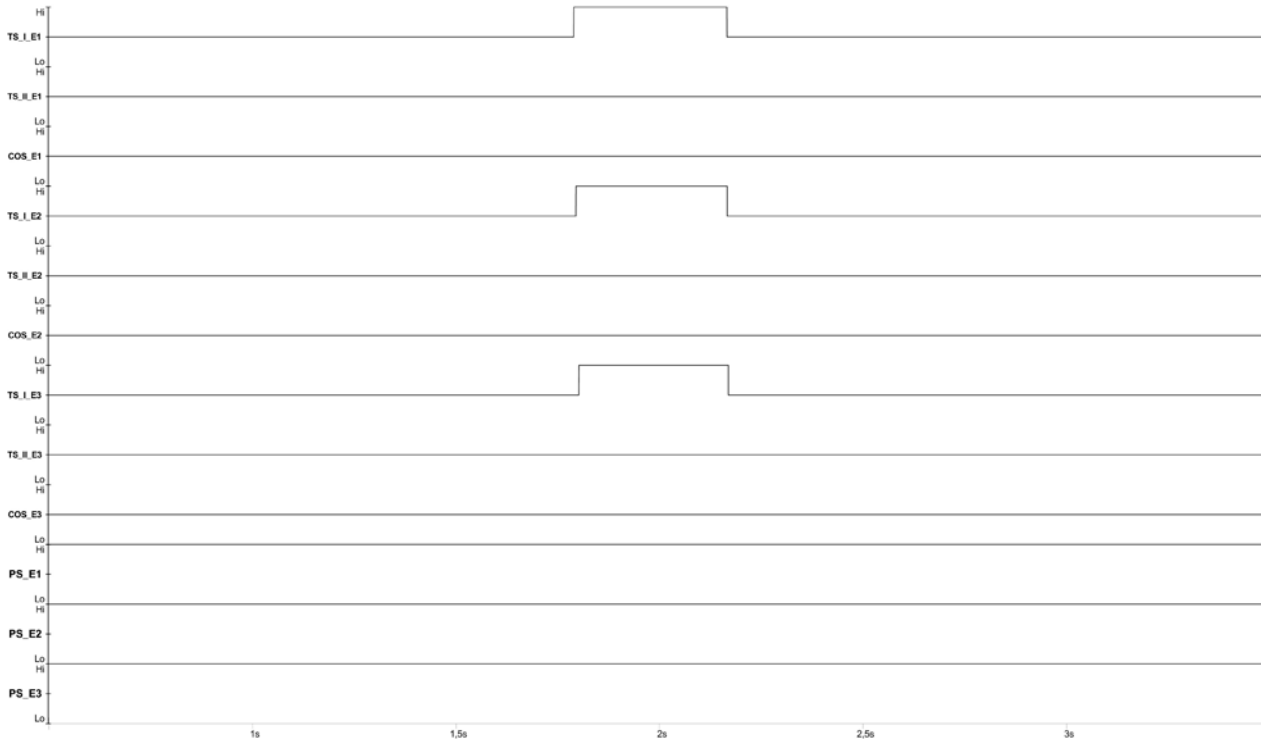

Fig. 4.7: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the beginning of the test.

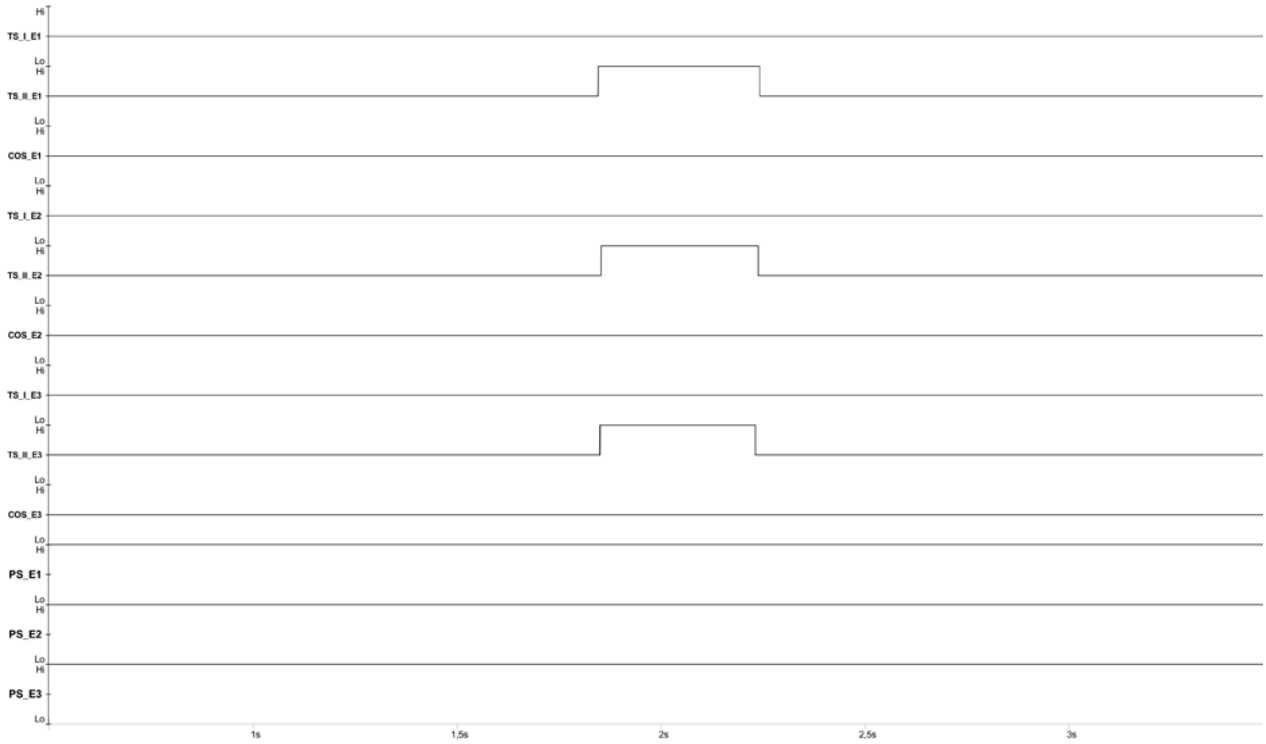

Fig. 4.8: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the beginning of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

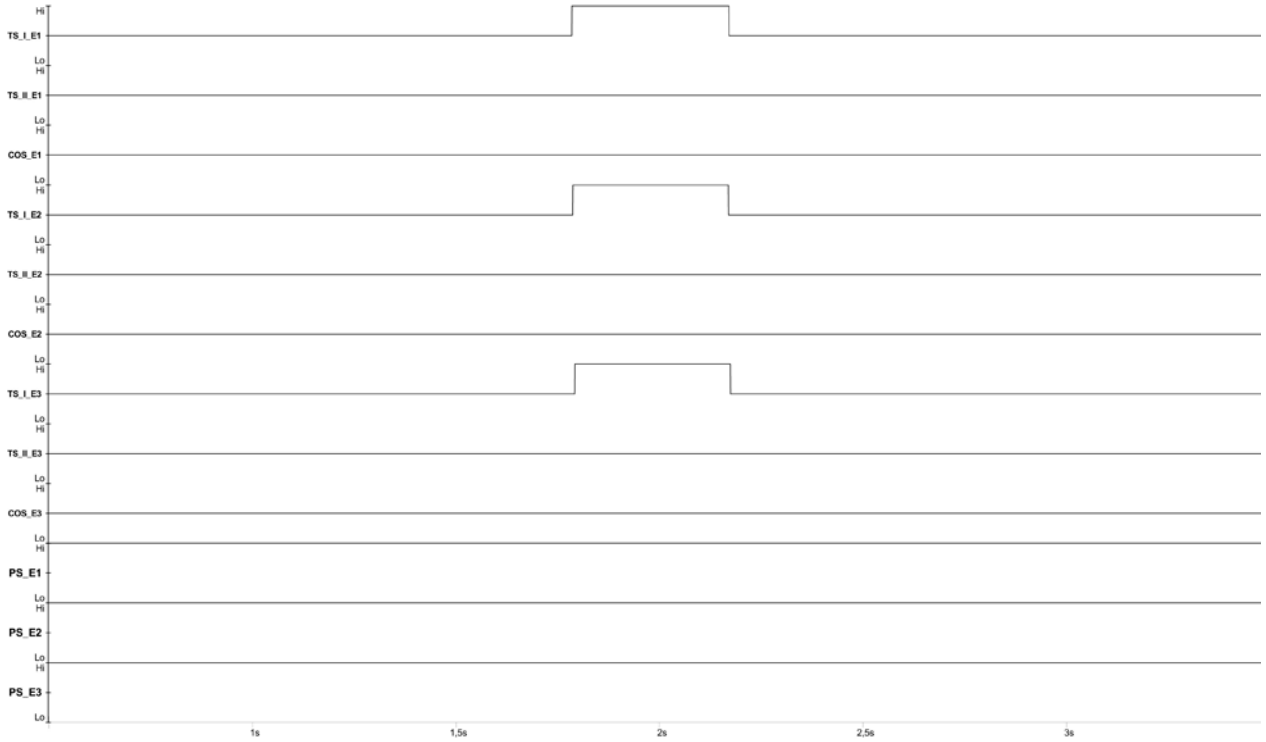

Fig. 4.9: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the beginning of the test.

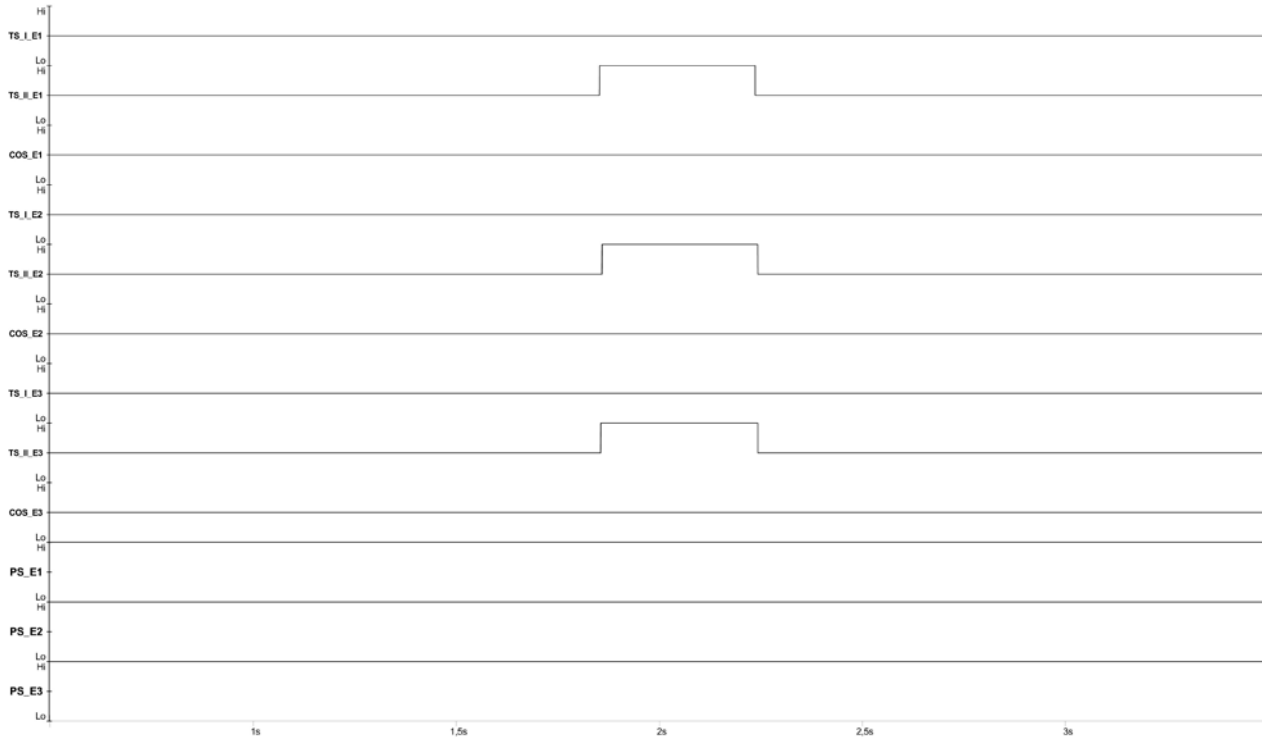

Fig. 4.10: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the beginning of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

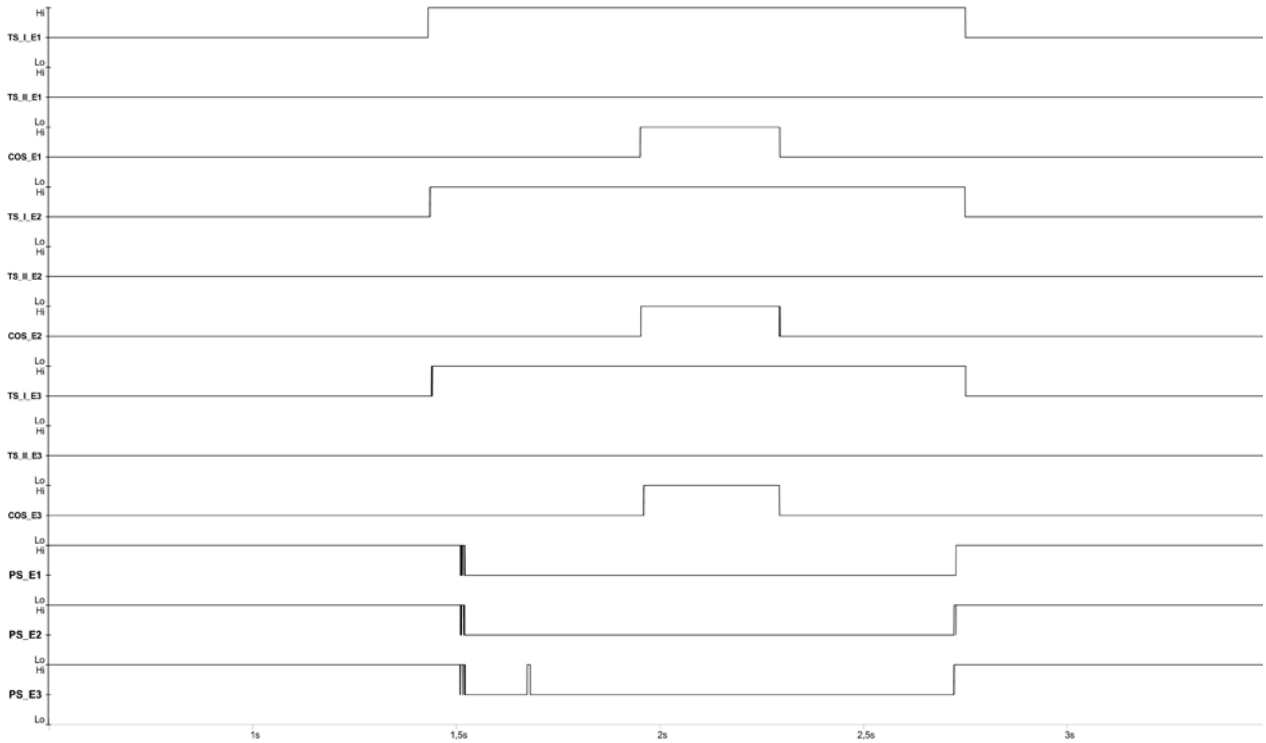

Fig. 4.11: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the end of the test.

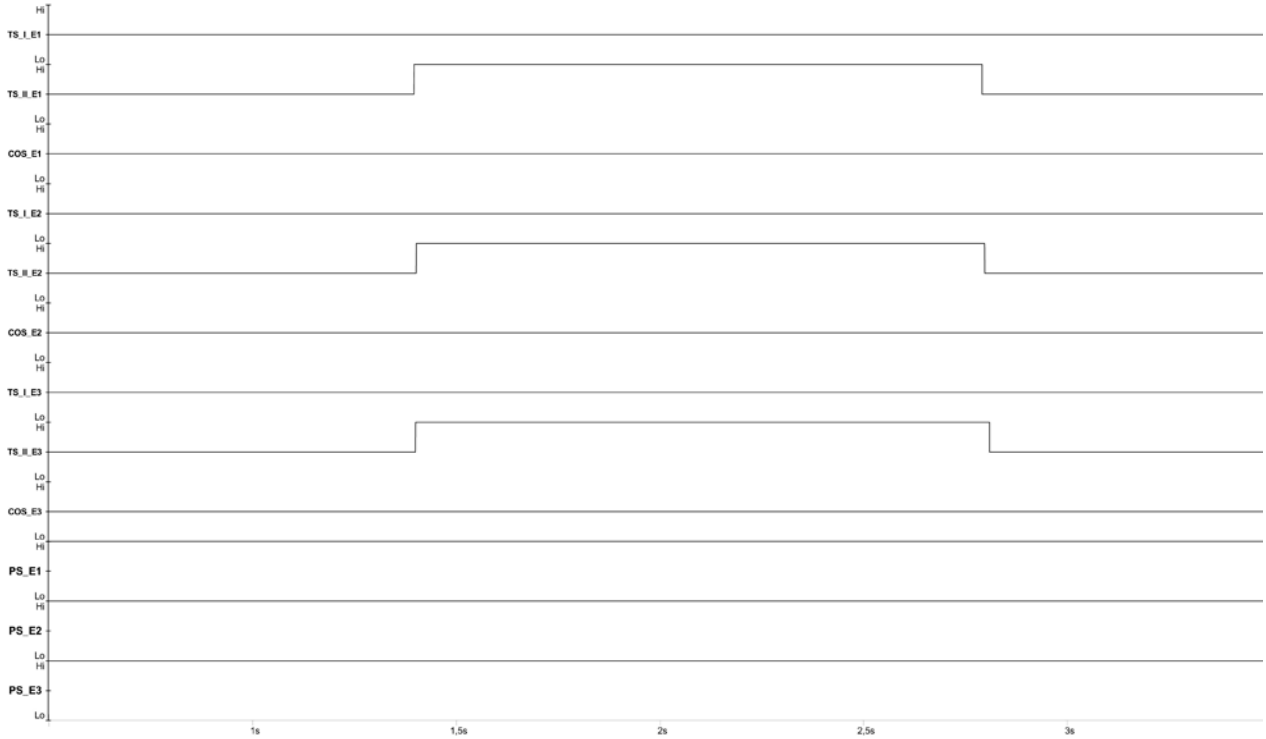

Fig. 4.12: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

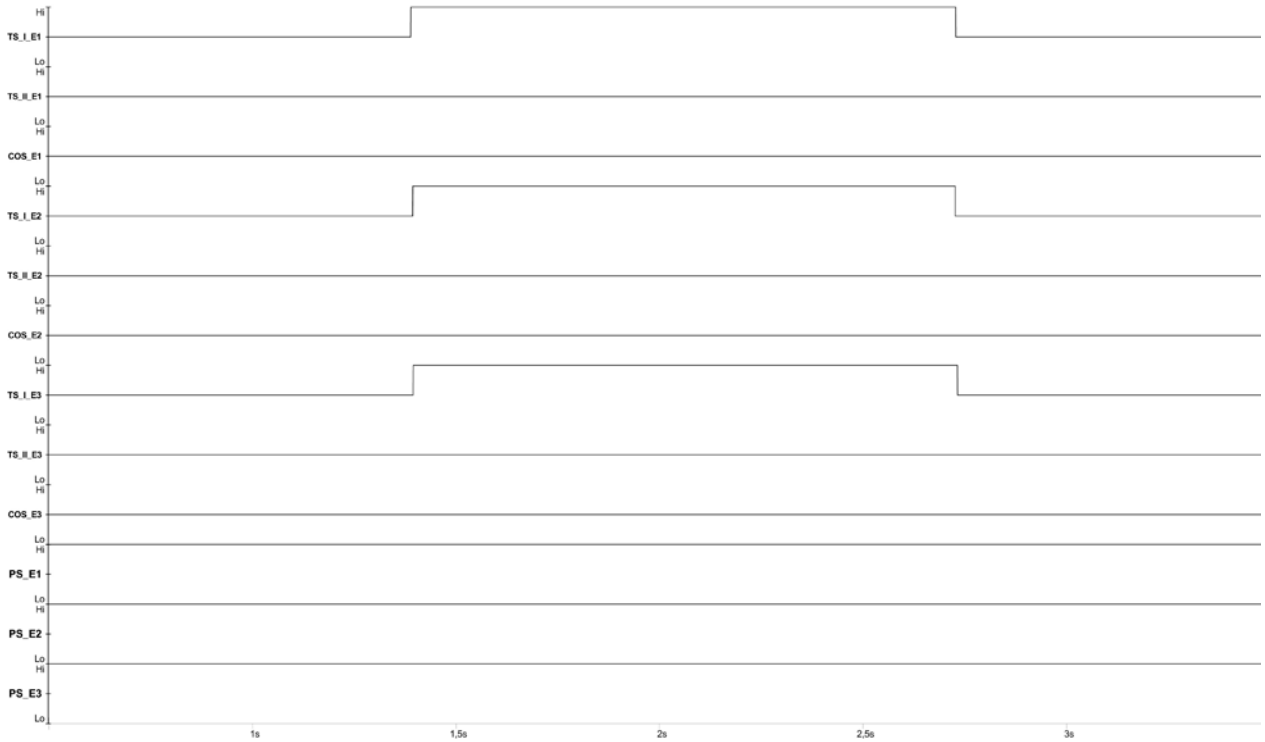

Fig. 4.13: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the end of the test.

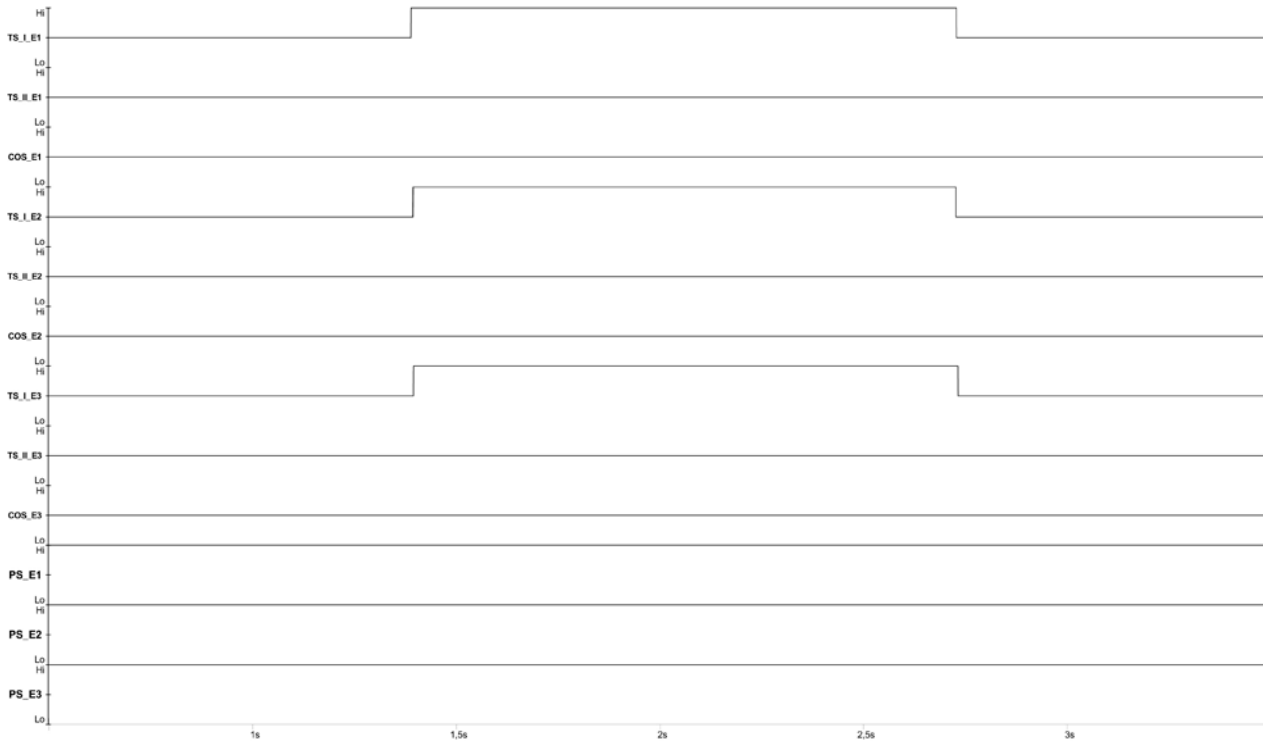

Fig. 4.14: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

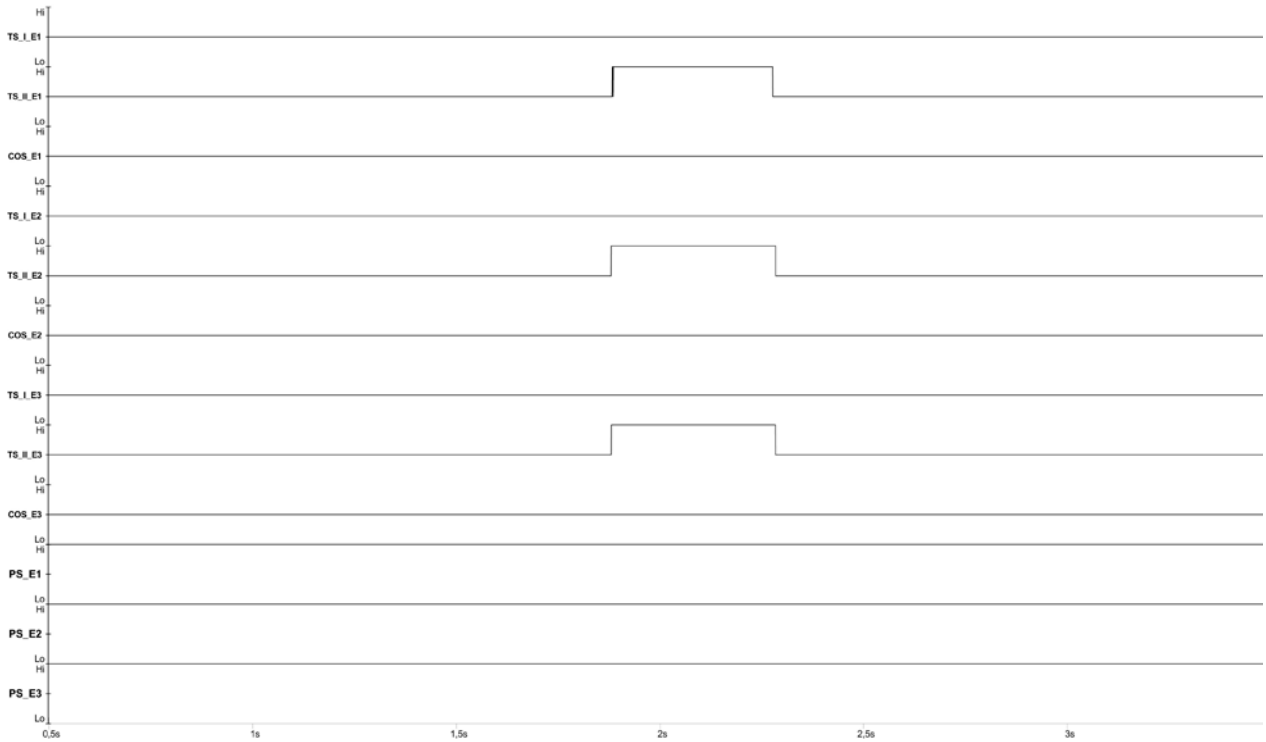

Fig. 4.15: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the end of the test.

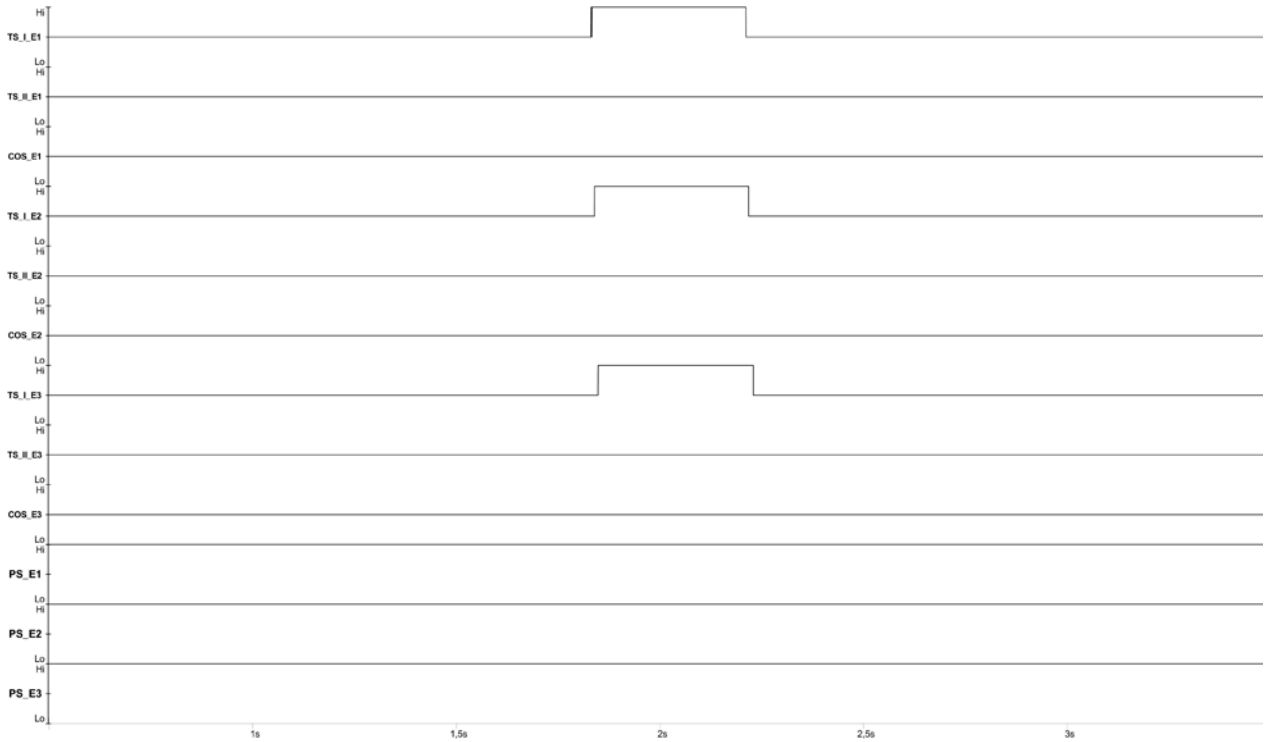

Fig. 4.16: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

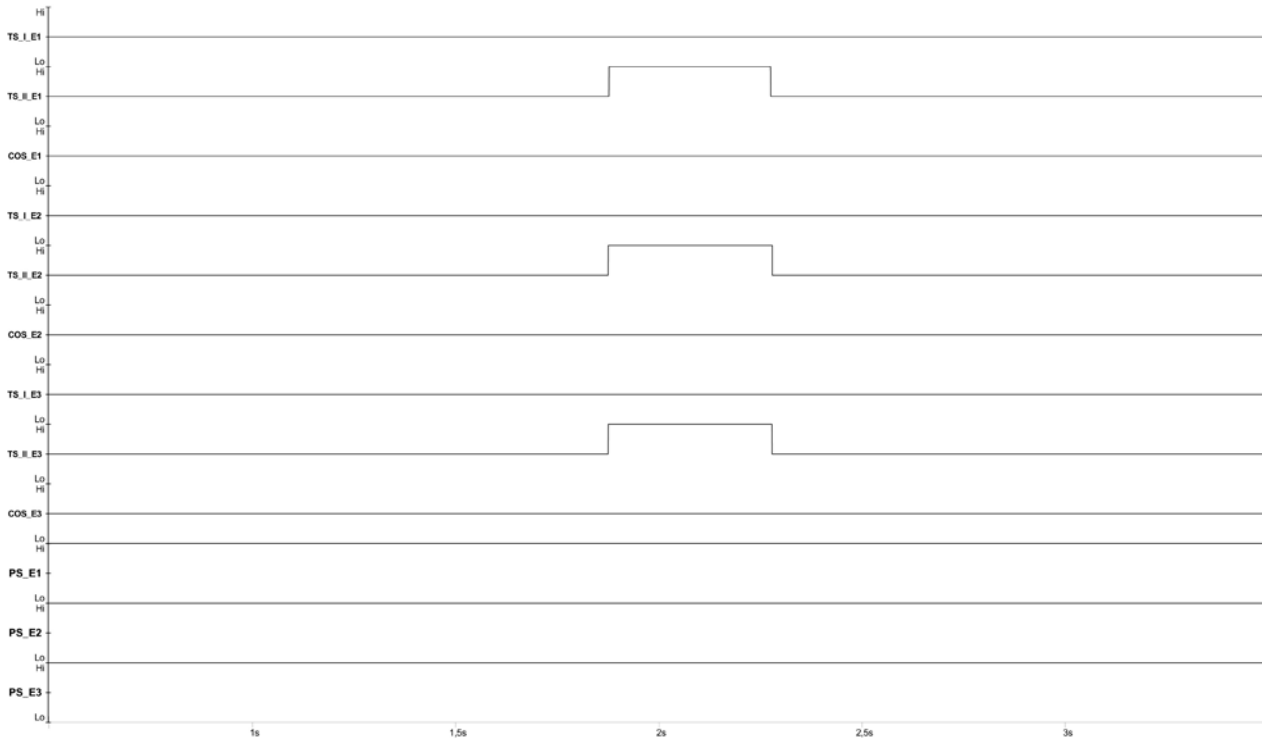

Fig. 4.17: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the end of the test.

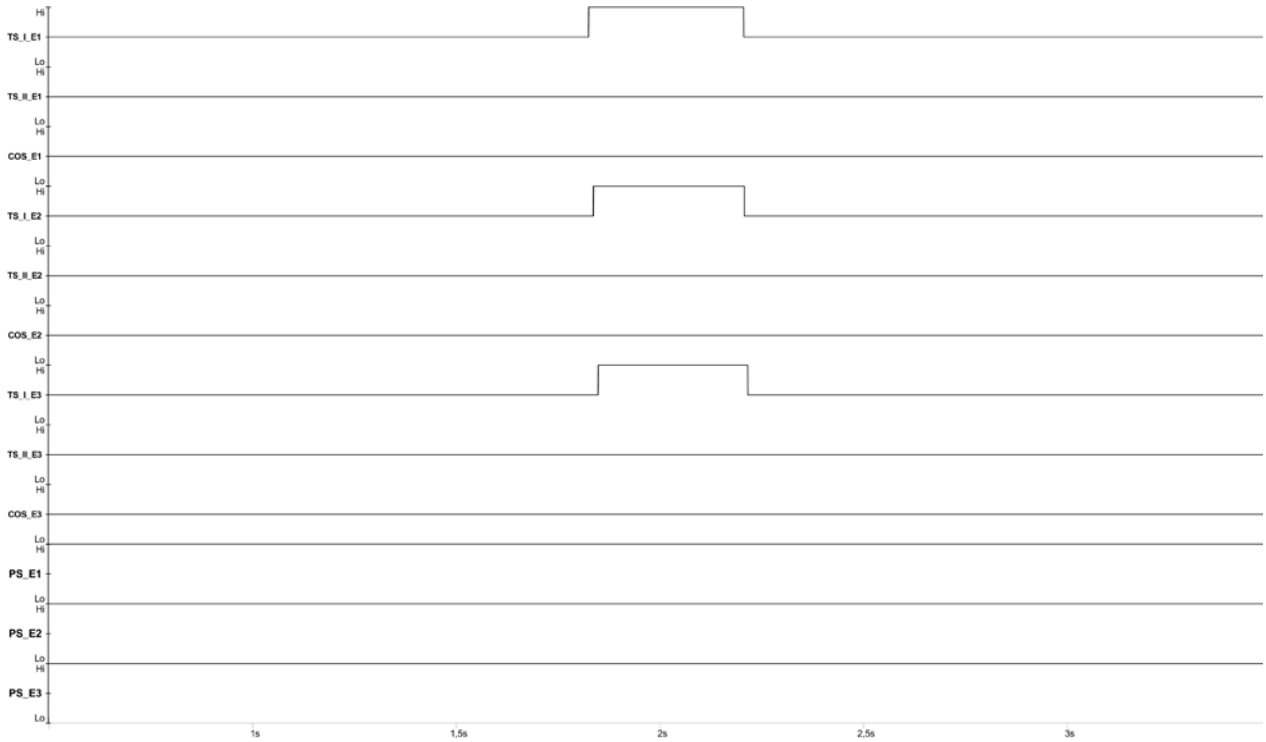

Fig. 4.18: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

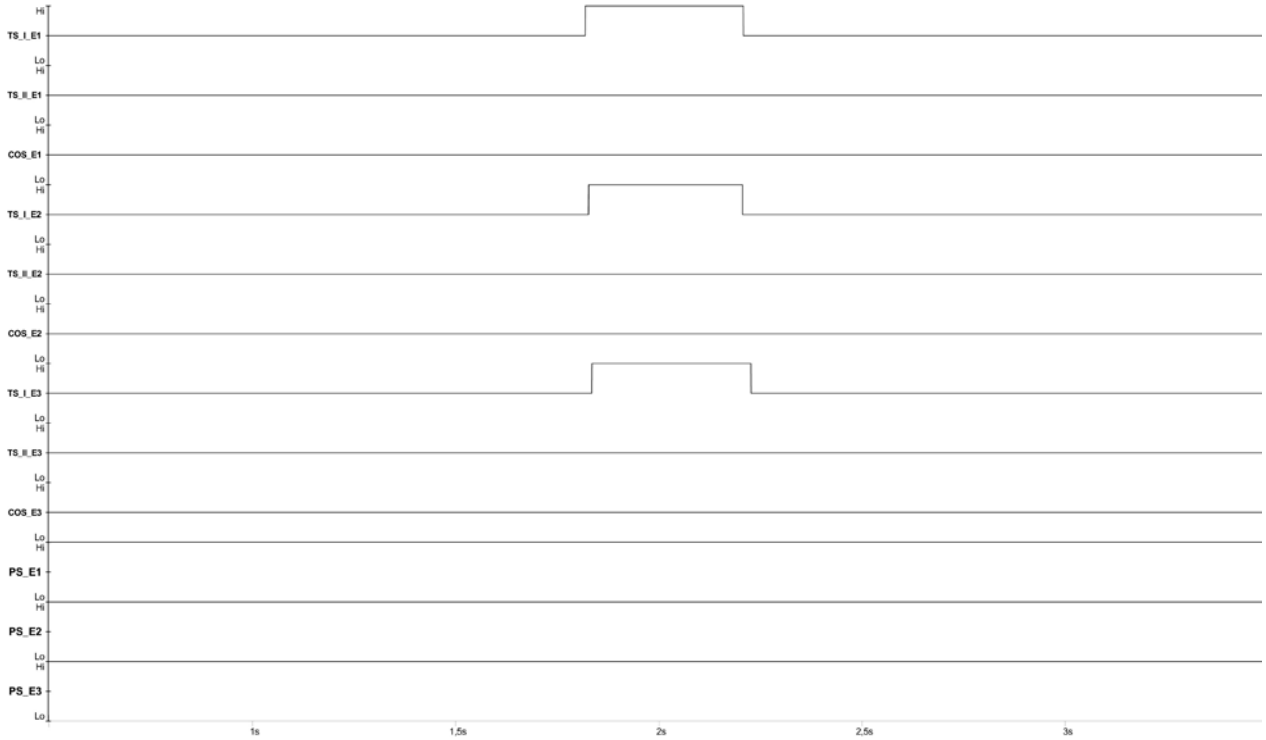

Fig. 4.19: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the end of the test.

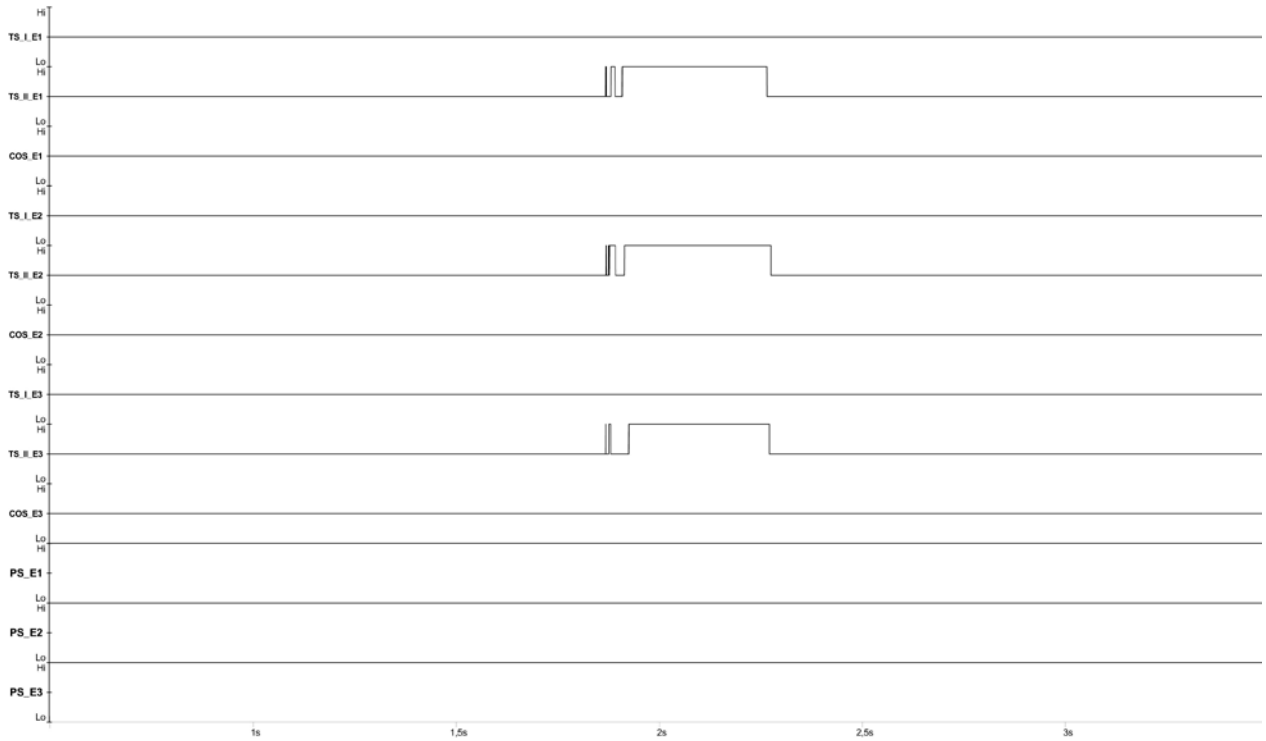

Fig. 4.20: Mechanical endurance test 500,000 operations (test sample 2) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

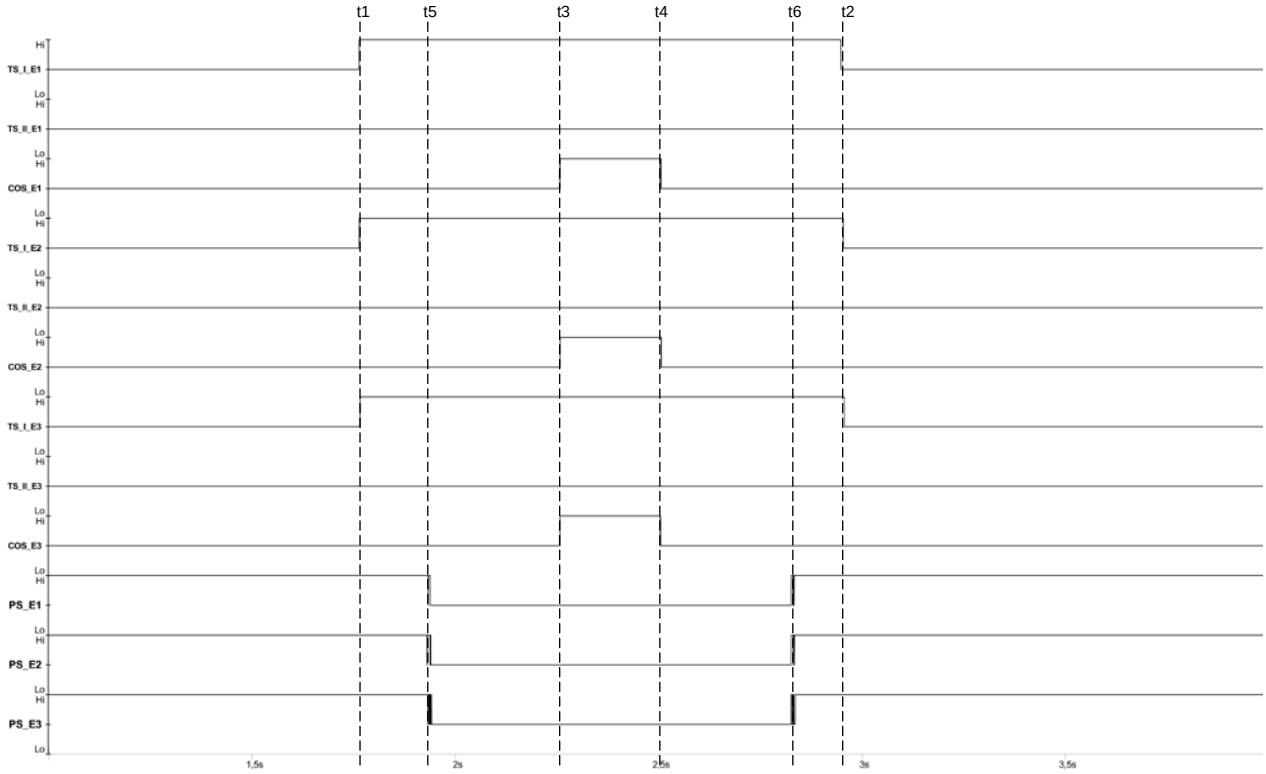

Fig. 5.1: Operation test at 105 °C (test sample 1) – Example of oscillogram at the beginning of the test.

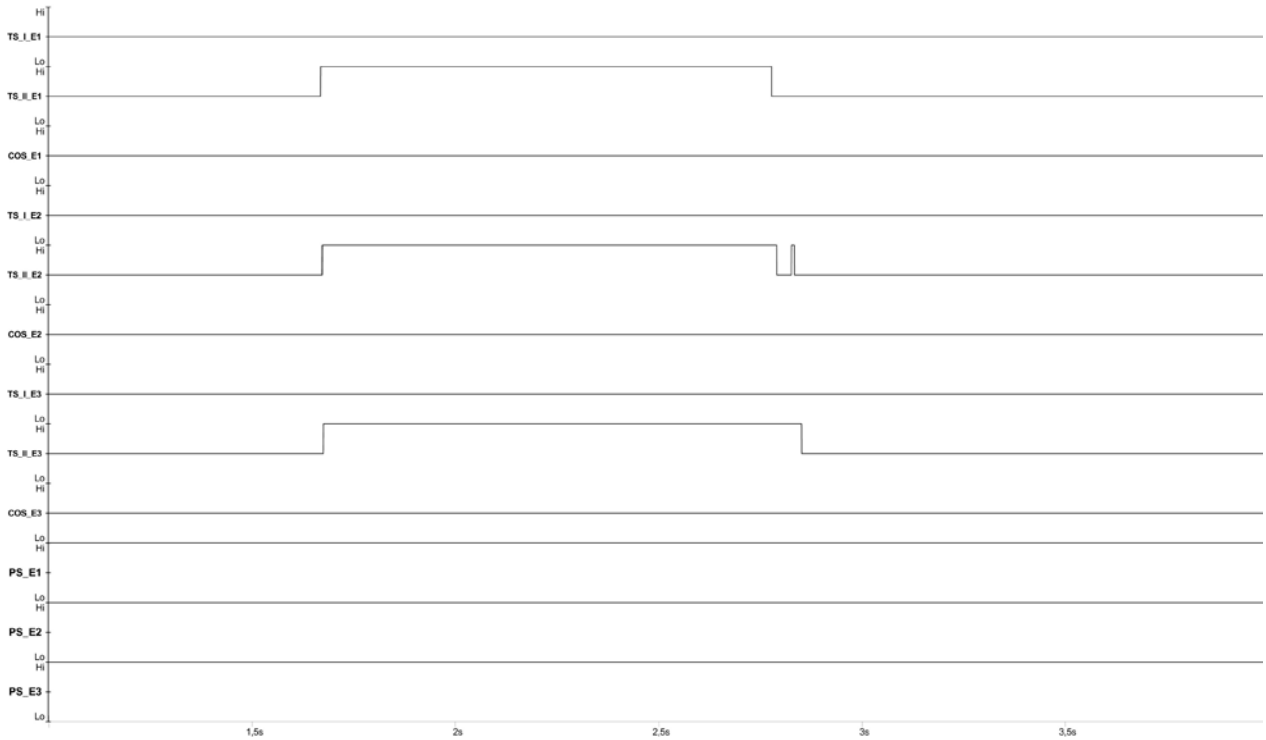

Fig. 5.2: Operation test at 105 °C (test sample 1) – Example of oscillogram at the beginning of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

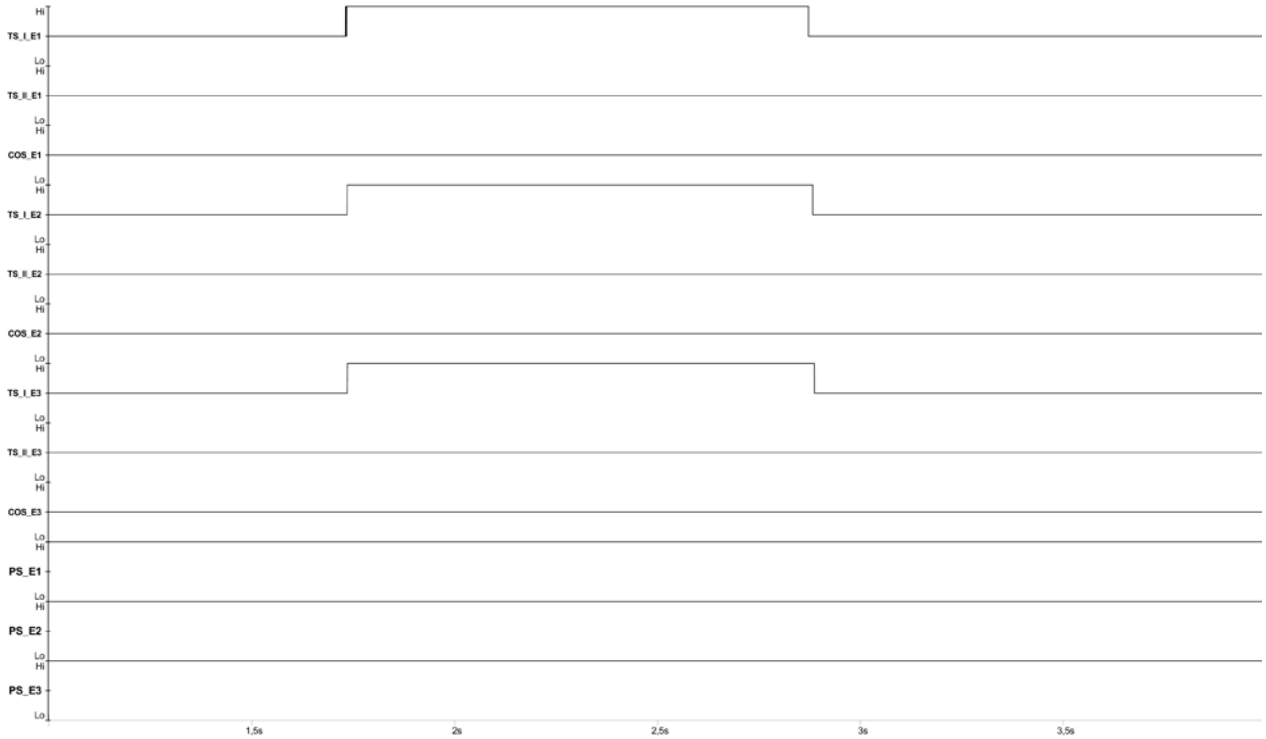

Fig. 5.3: Operation test at 105 °C (test sample 1) – Example of oscillogram at the beginning of the test.

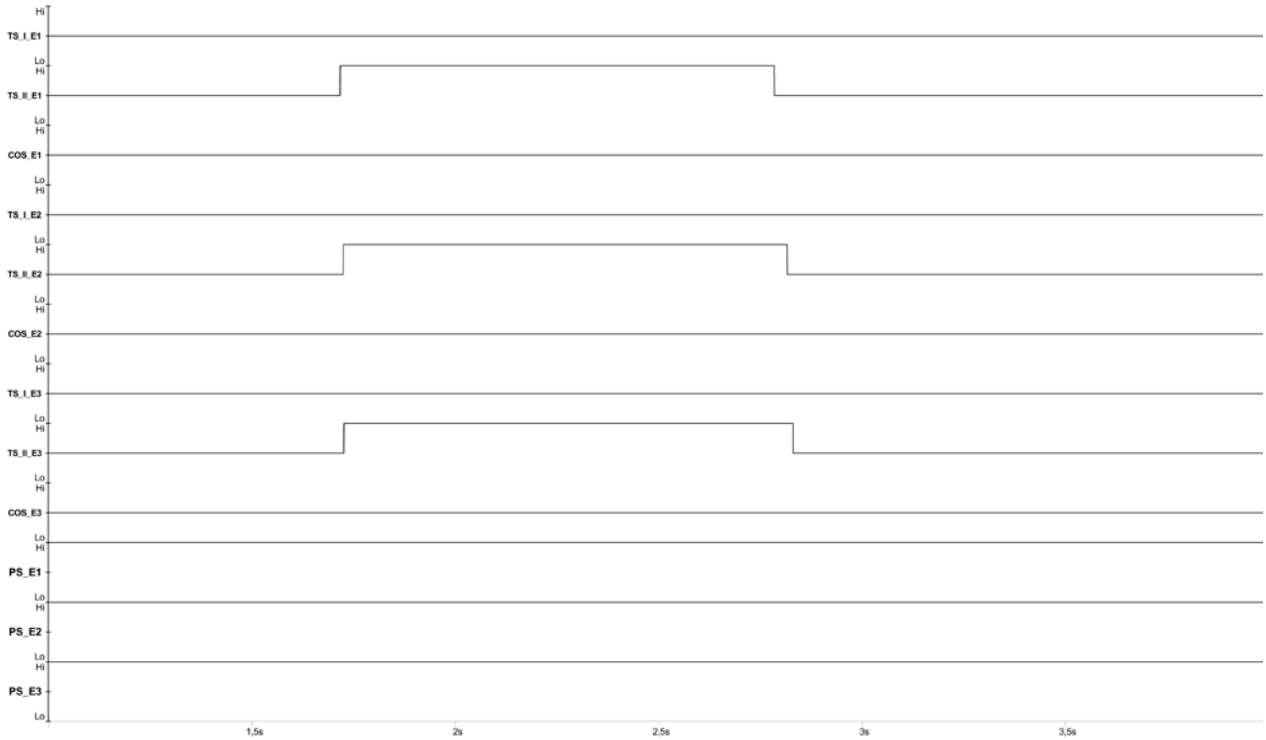

Fig. 5.4: Operation test at 105 °C (test sample 1) – Example of oscillogram at the beginning of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

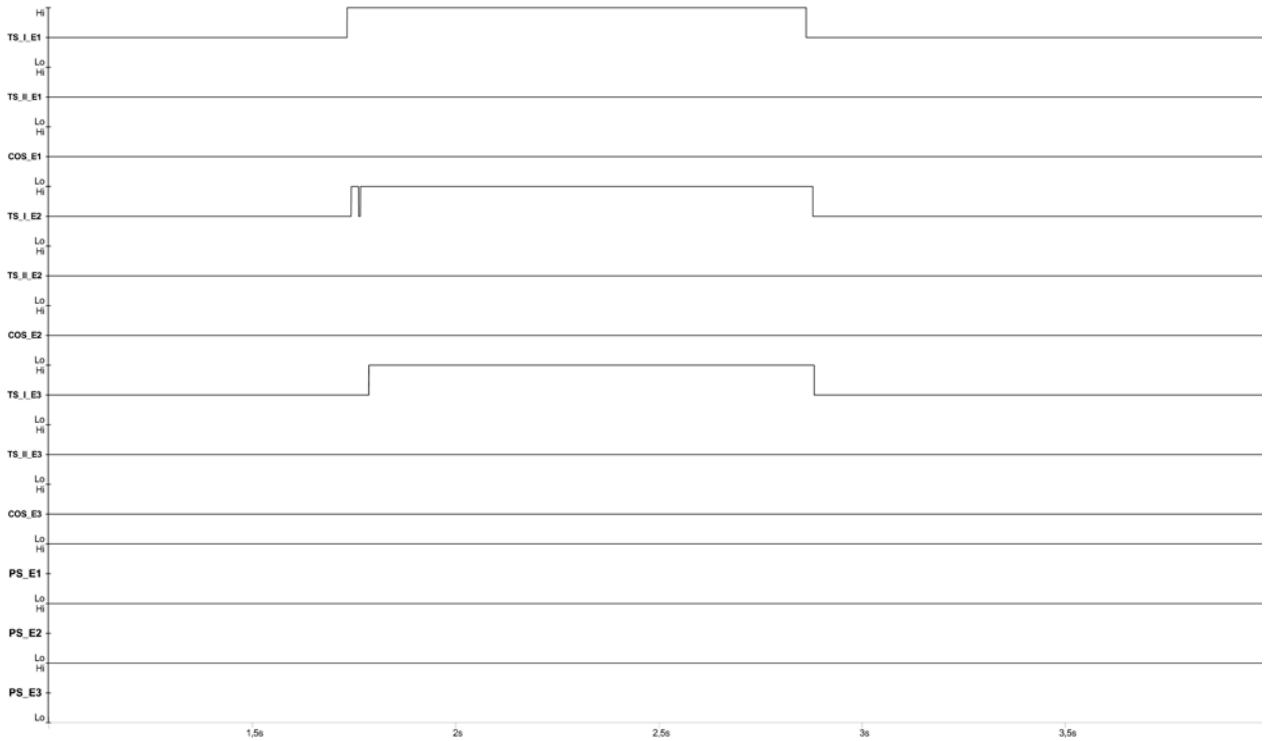

Fig. 5.5: Operation test at 105 °C (test sample 1) – Example of oscillogram at the beginning of the test.

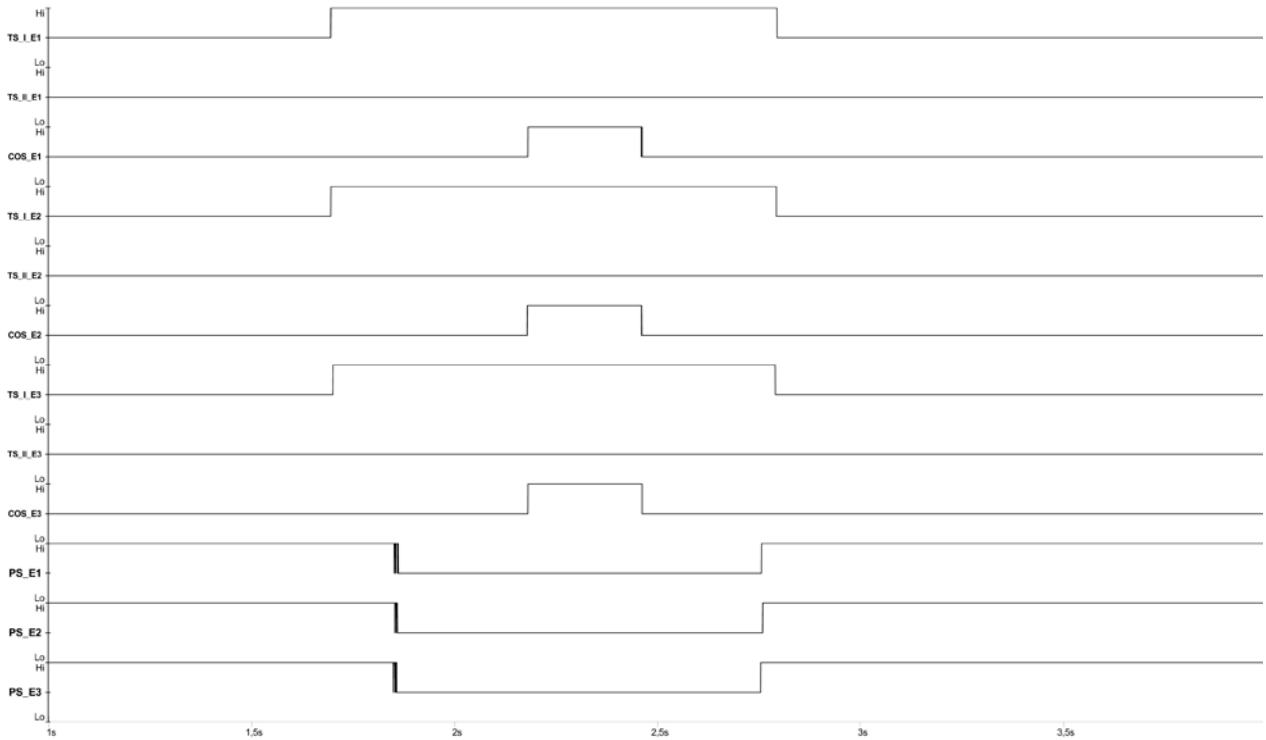

Fig. 5.6: Operation test at 105 °C (test sample 1) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

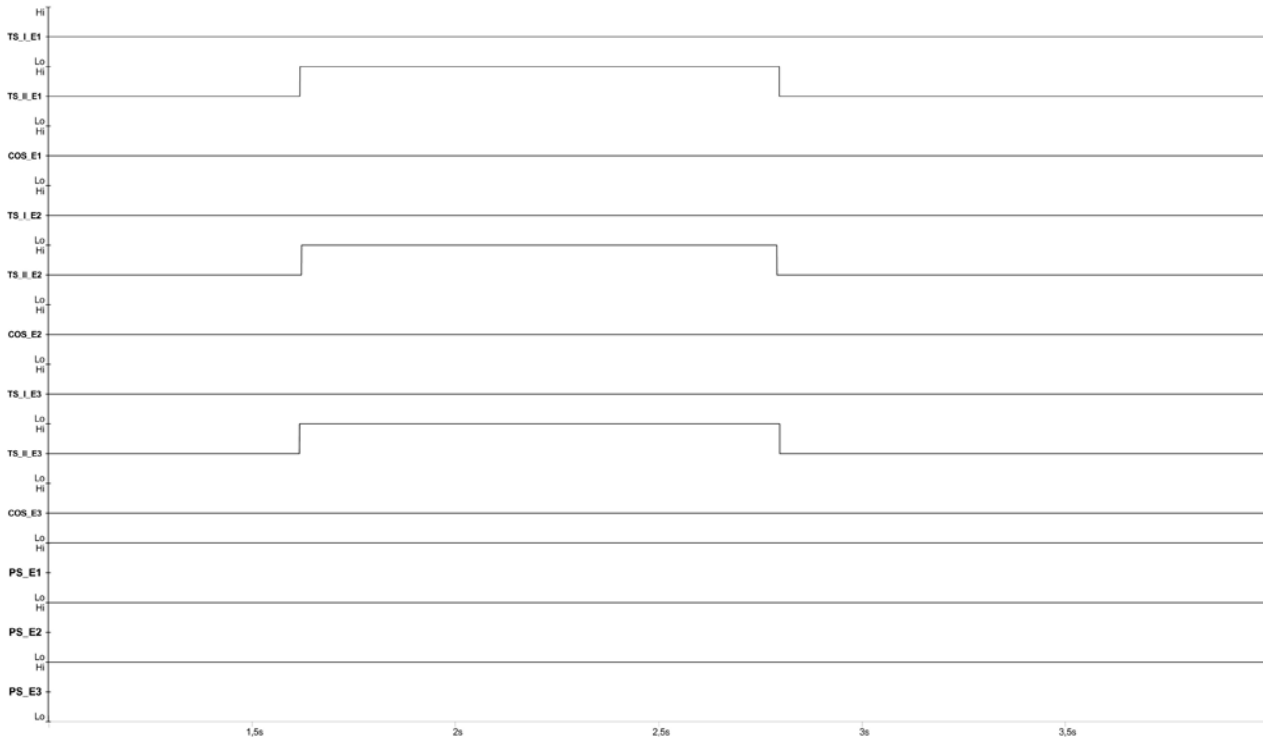

Fig. 5.7: Operation test at 105 °C (test sample 1) – Example of oscillogram at the end of the test.

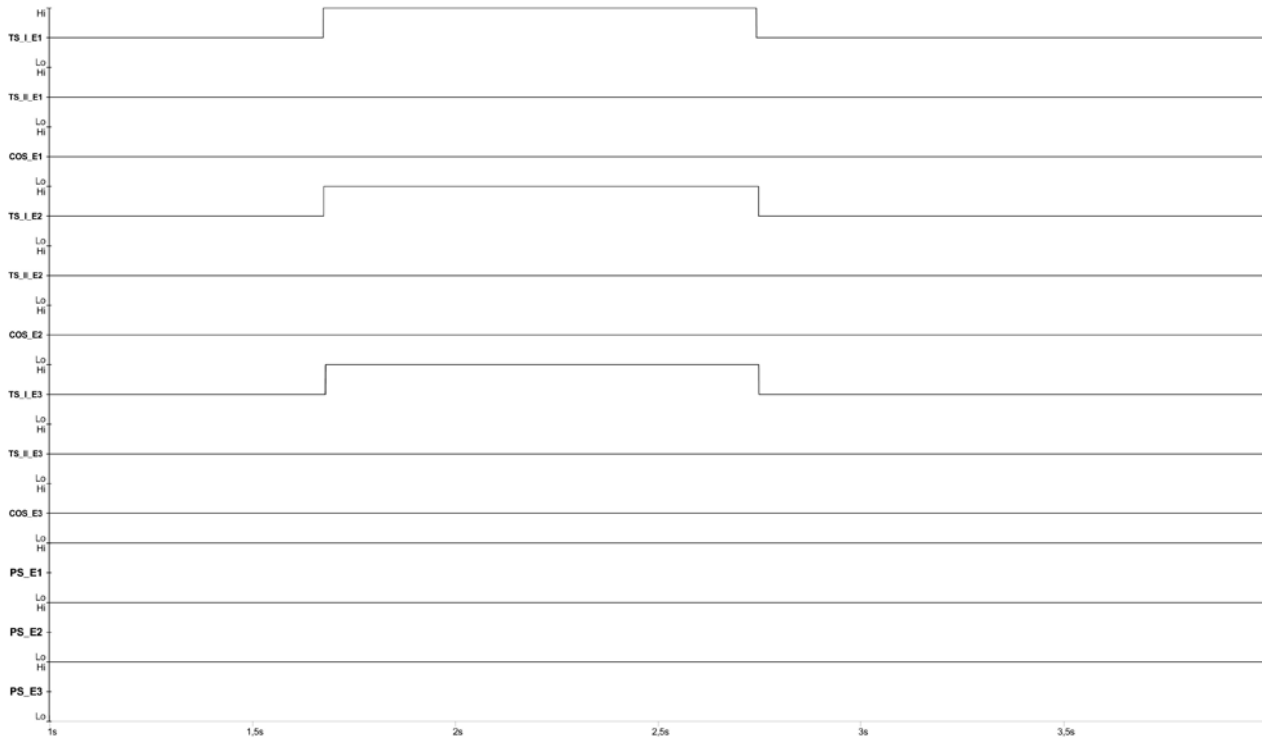

Fig. 5.8: Operation test at 105 °C (test sample 1) – Example of oscillogram at the end of the test.

TS_I, TS_II: Tap selector arm 1, 2
E1, E2, E3: Contact planes 1, 2, 3
COS: Change-over selector
PS: Potential switch

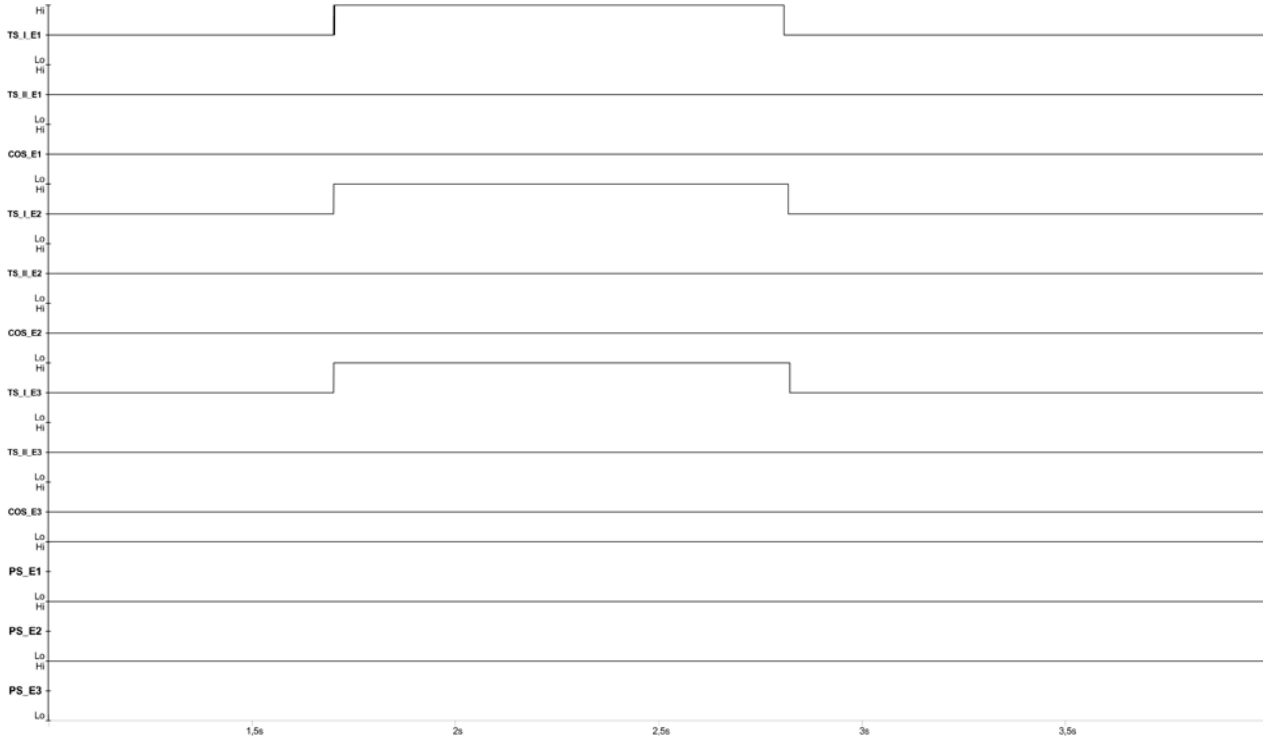

Fig. 5.9: Operation test at 105 °C (test sample 1) – Example of oscillogram at the end of the test.

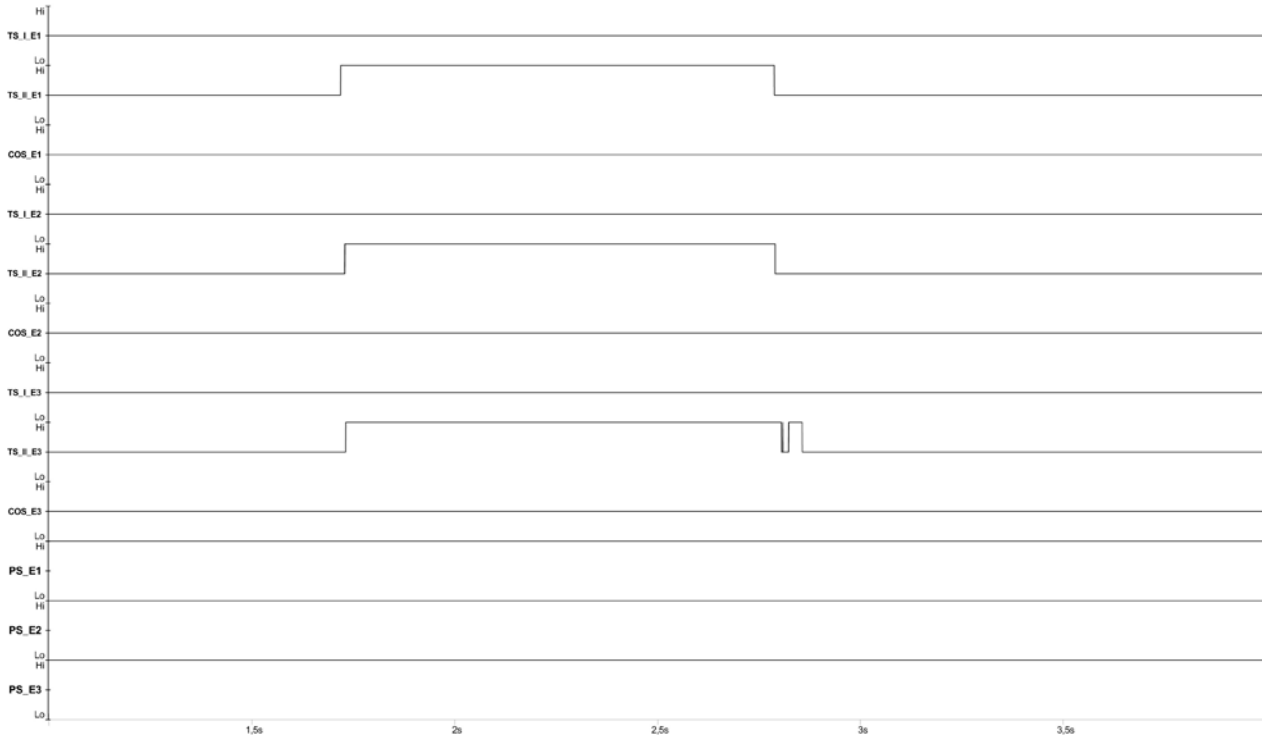

Fig. 5.10: Operation test at 105 °C (test sample 1) – Example of oscillogram at the end of the test.

TS_I, TS_II: Tap selector arm 1, 2
E1, E2, E3: Contact planes 1, 2, 3
COS: Change-over selector
PS: Potential switch

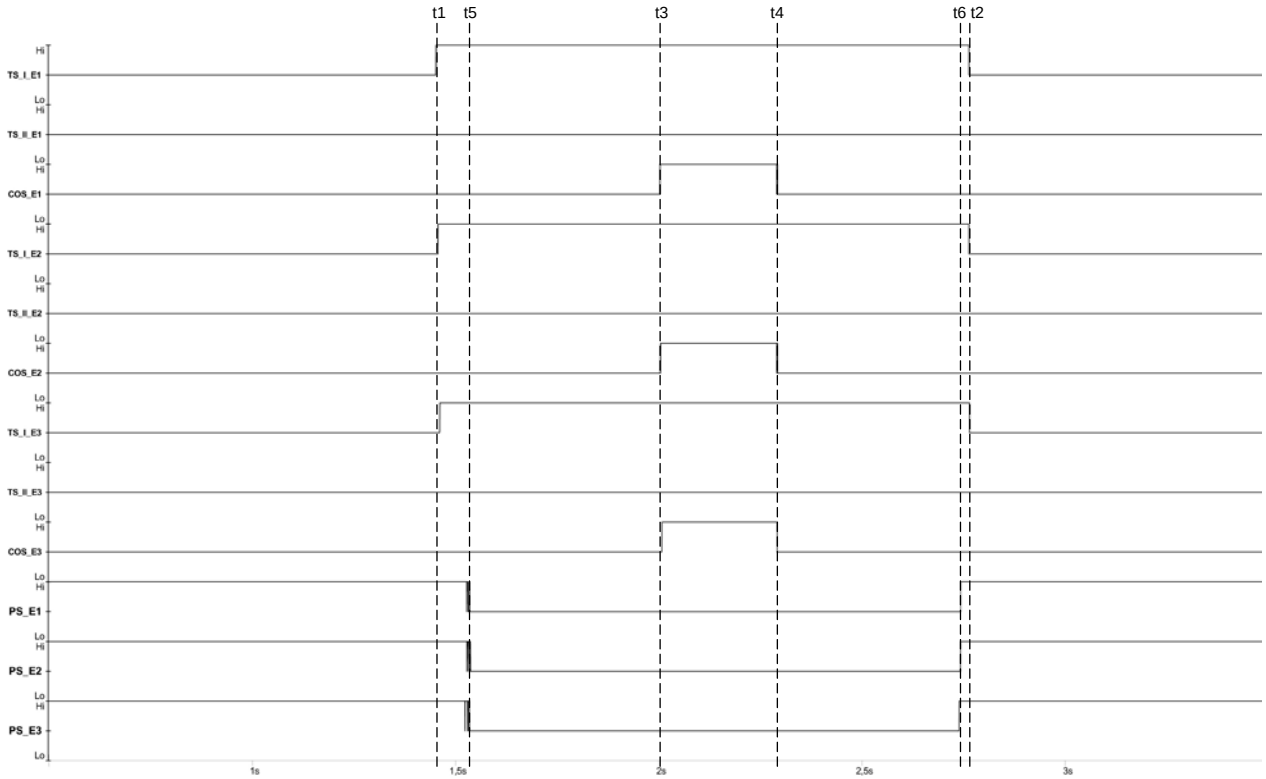

Fig. 6.1: Operation test at 105 °C (test sample 2) – Example of oscillogram at the beginning of the test.

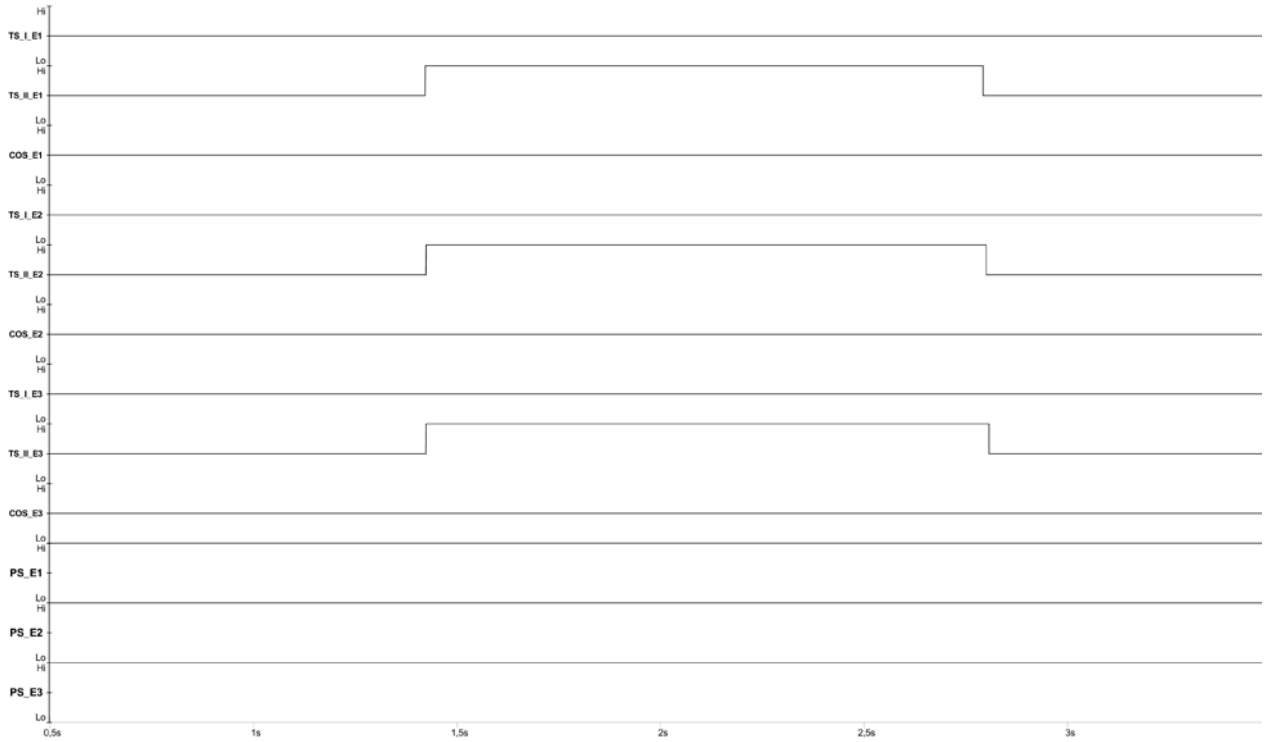

Fig. 6.2: Operation test at 105 °C (test sample 2) – Example of oscillogram at the beginning of the test.

TS_I, TS_II: Tap selector arm 1, 2
E1, E2, E3: Contact planes 1, 2, 3
COS: Change-over selector
PS: Potential switch

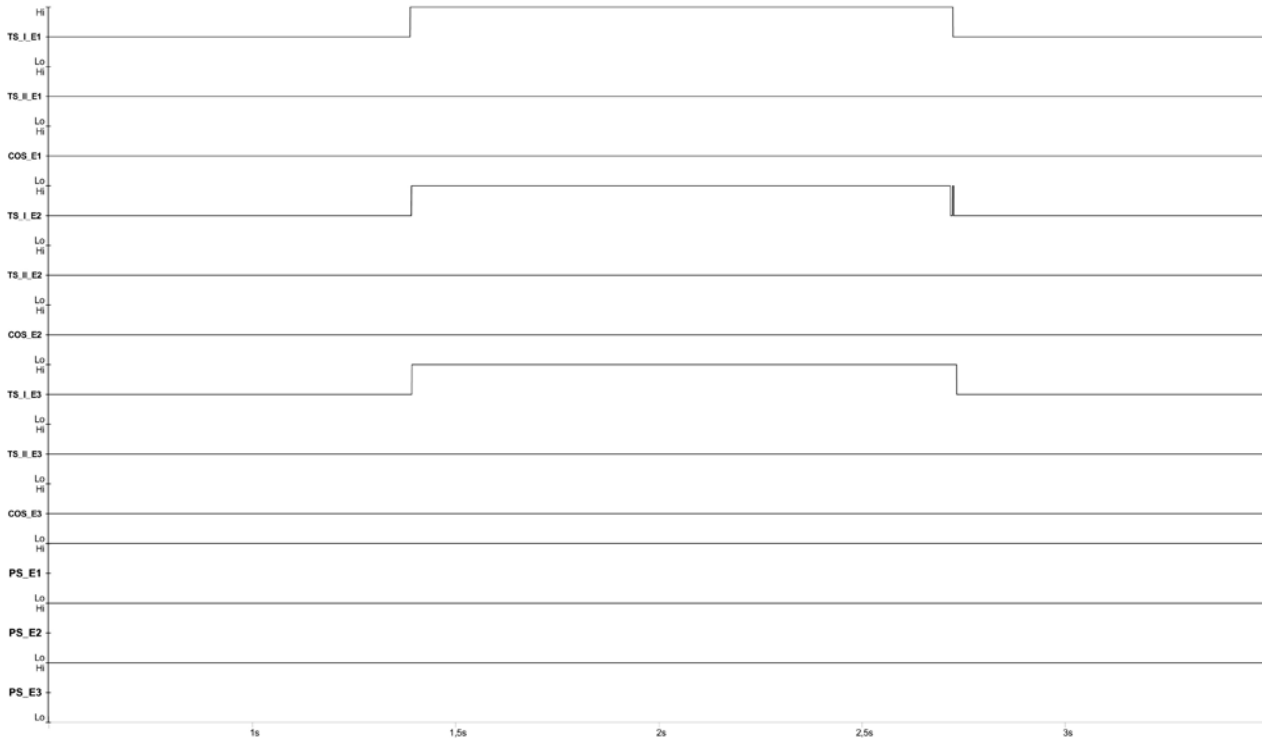

Fig. 6.3: Operation test at 105 °C (test sample 2) – Example of oscillogram at the beginning of the test.

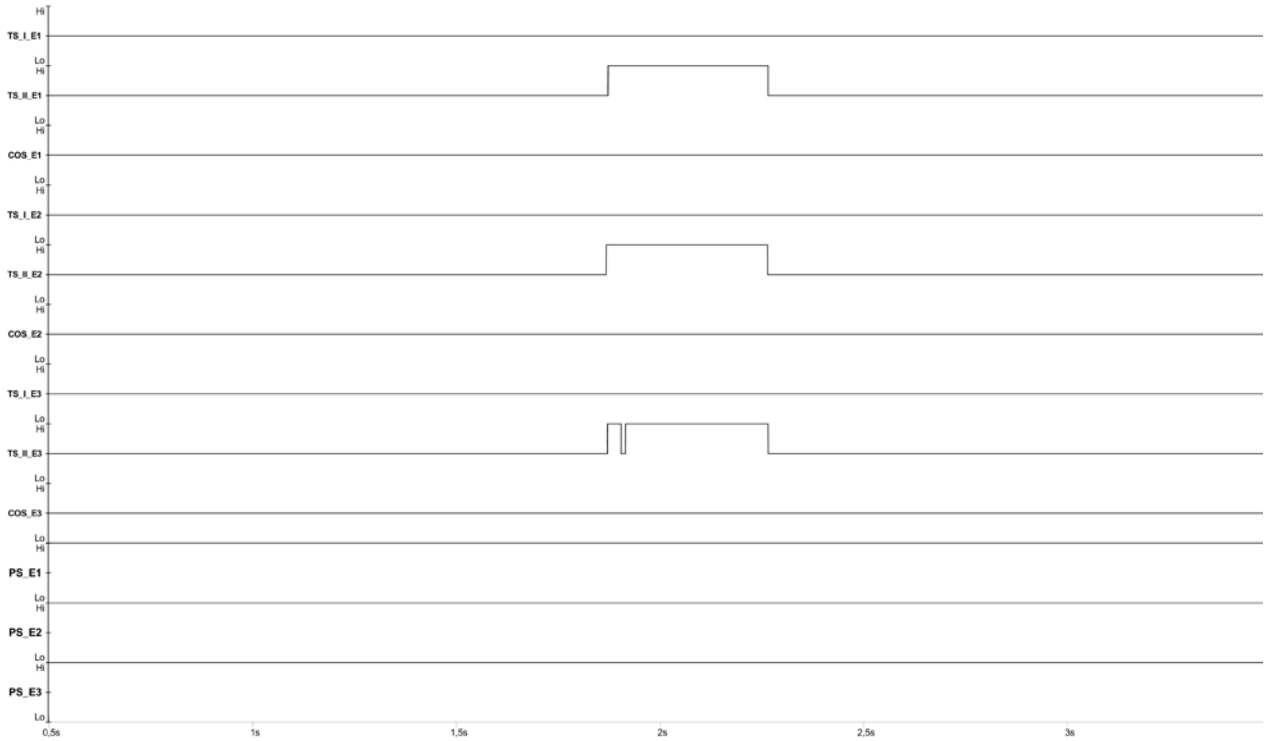

Fig. 6.4: Operation test at 105 °C (test sample 2) – Example of oscillogram at the beginning of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

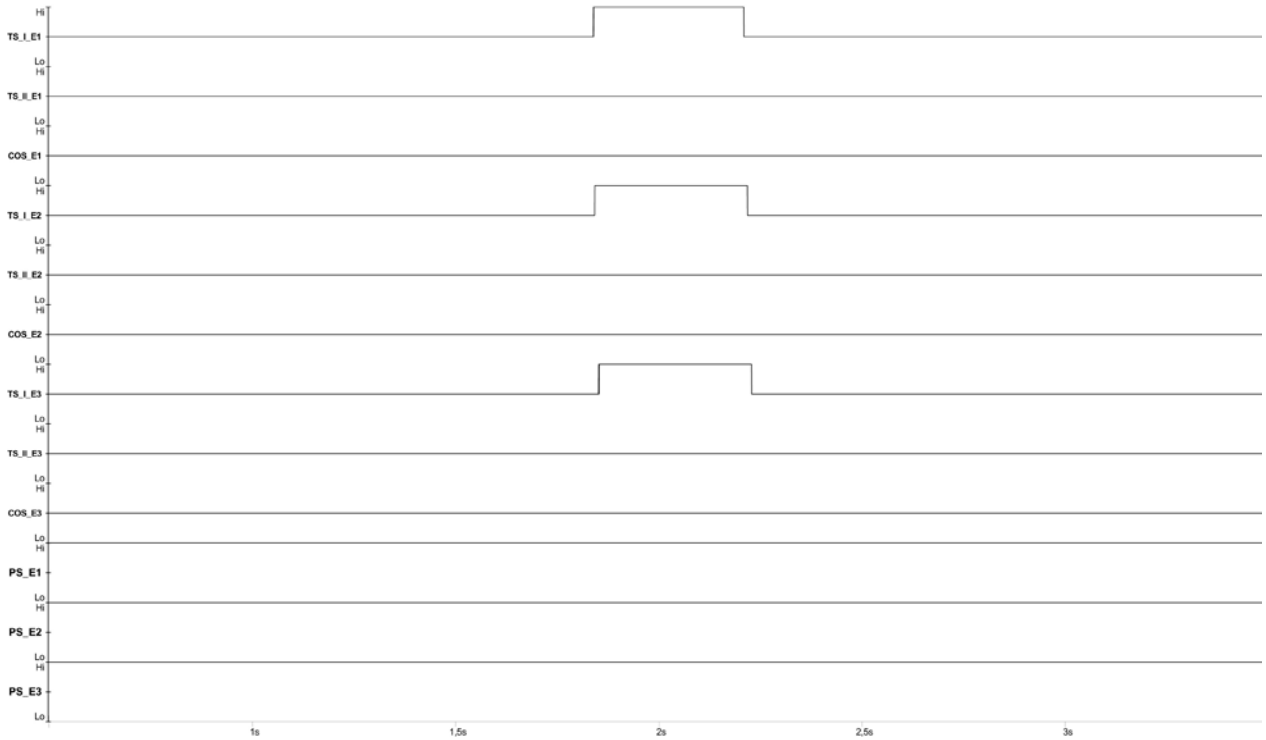

Fig. 6.5: Operation test at 105 °C (test sample 2) – Example of oscillogram at the beginning of the test.

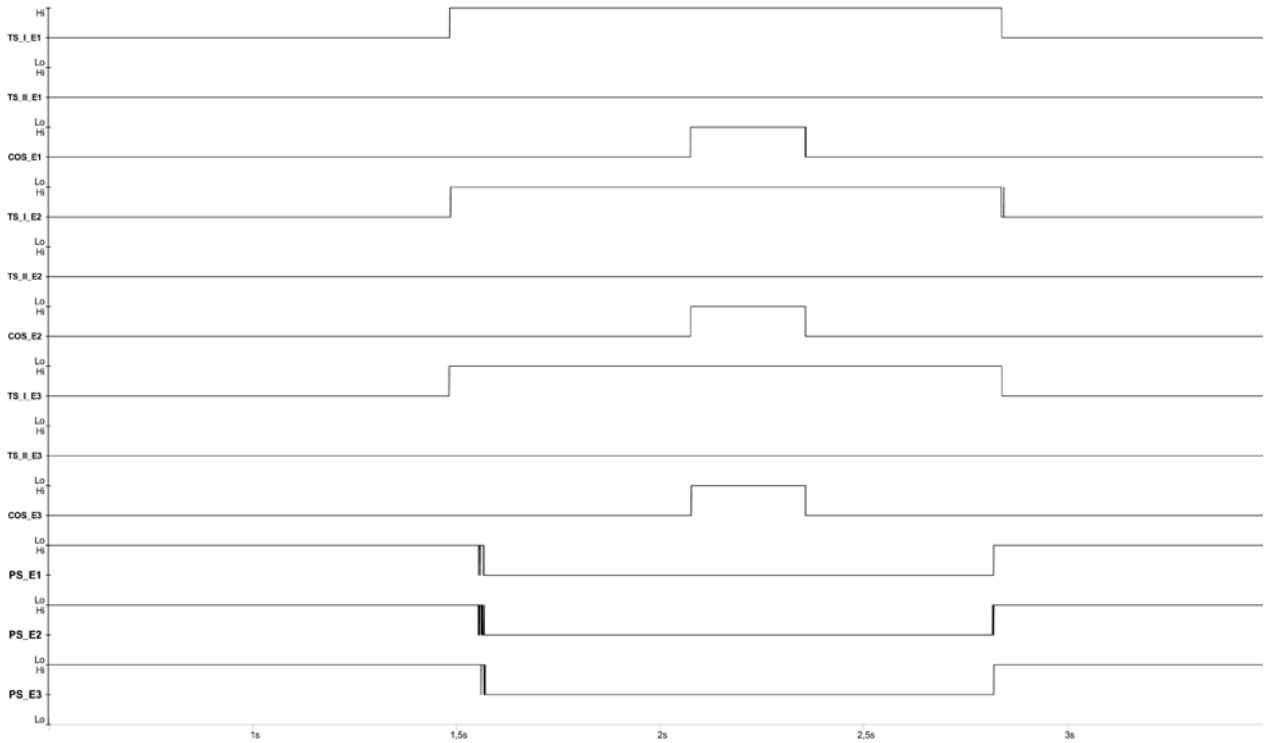

Fig. 6.6: Operation test at 105 °C (test sample 2) – Example of oscillogram at the end of the test.

TS_I, TS_II: Tap selector arm 1, 2
E1, E2, E3: Contact planes 1, 2, 3
COS: Change-over selector
PS: Potential switch

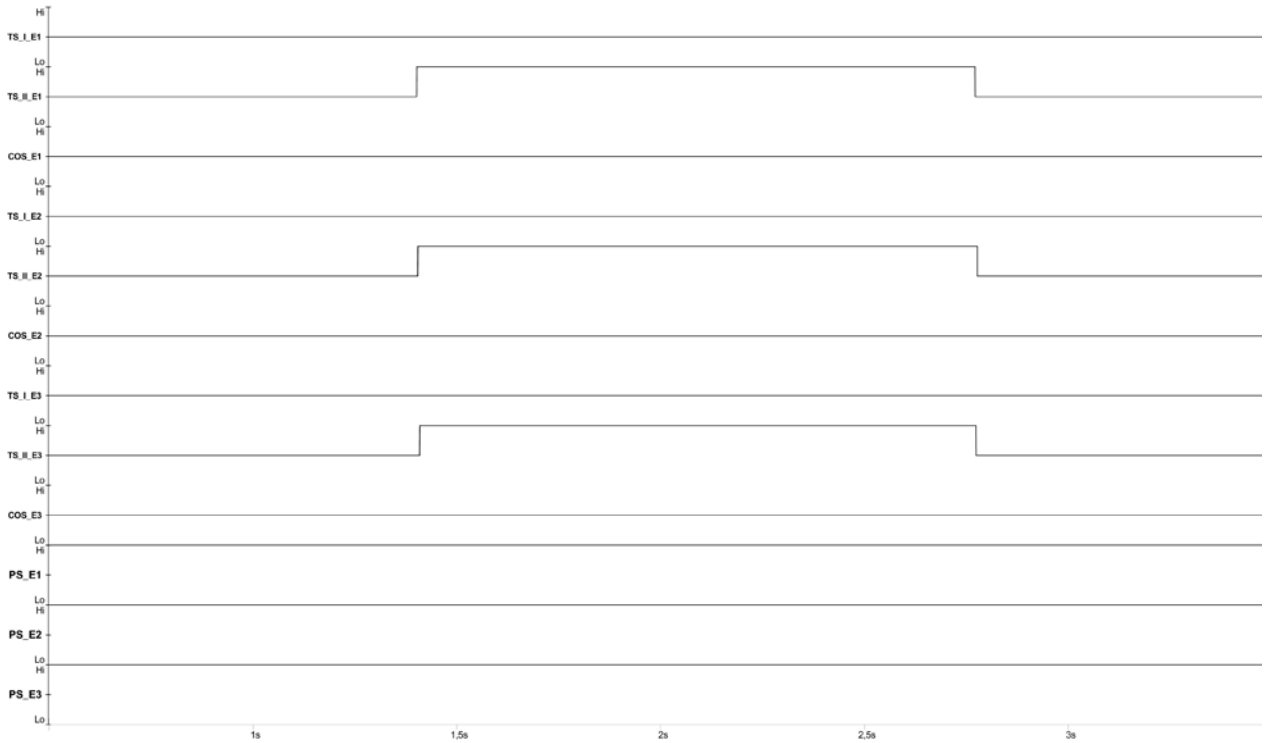

Fig. 6.7: Operation test at 105 °C (test sample 2) – Example of oscillogram at the end of the test.

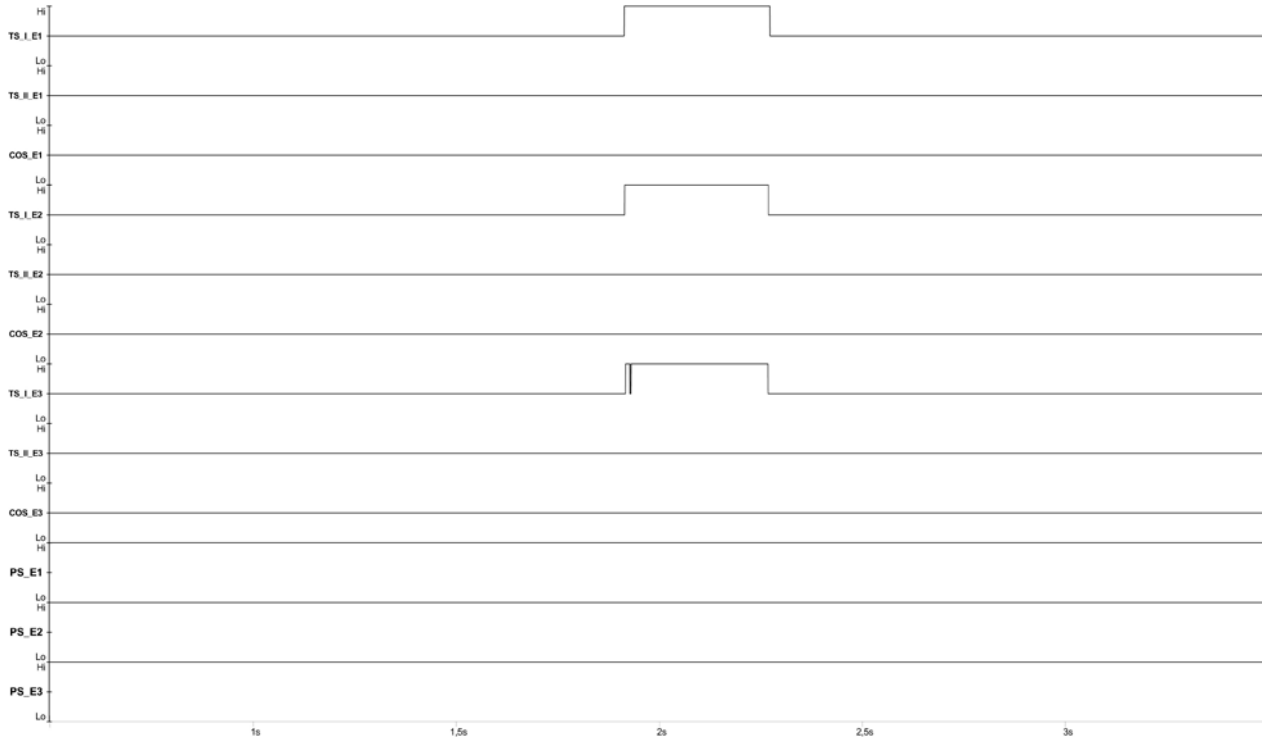

Fig. 6.8: Operation test at 105 °C (test sample 2) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

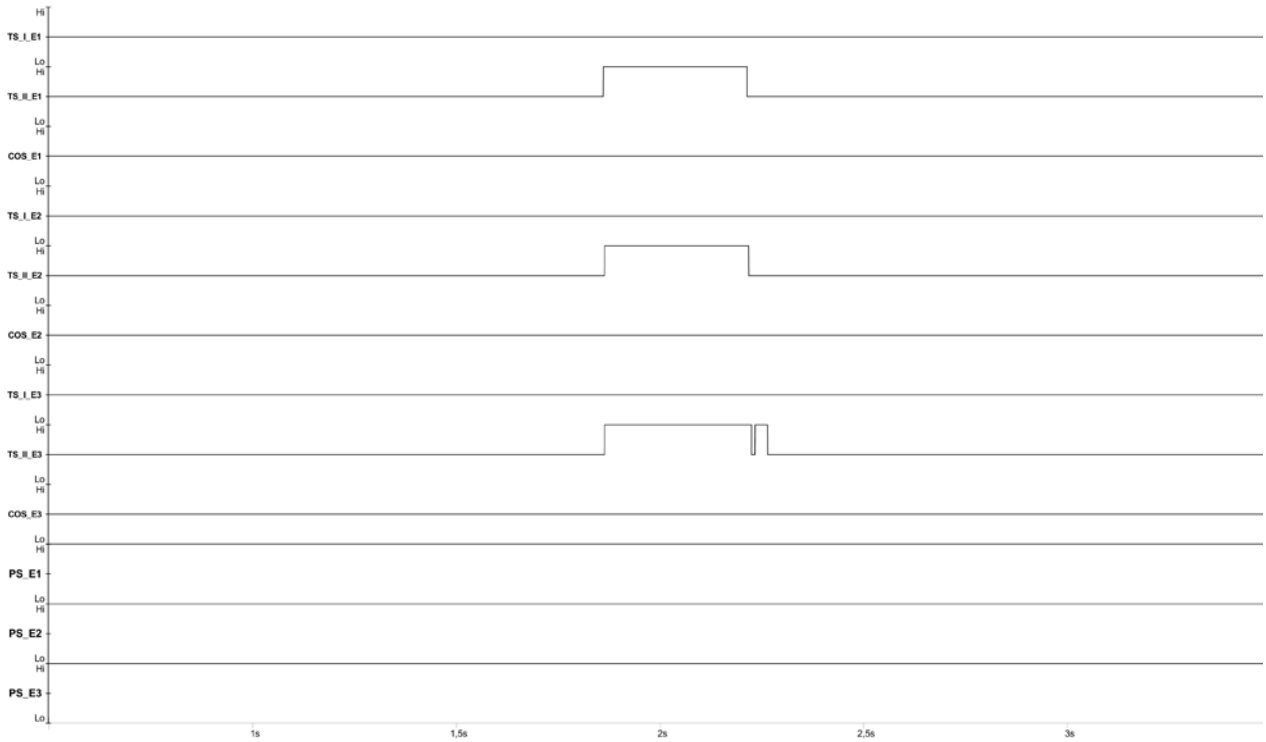

Fig. 6.9: Operation test at 105 °C (test sample 2) – Example of oscillogram at the end of the test.

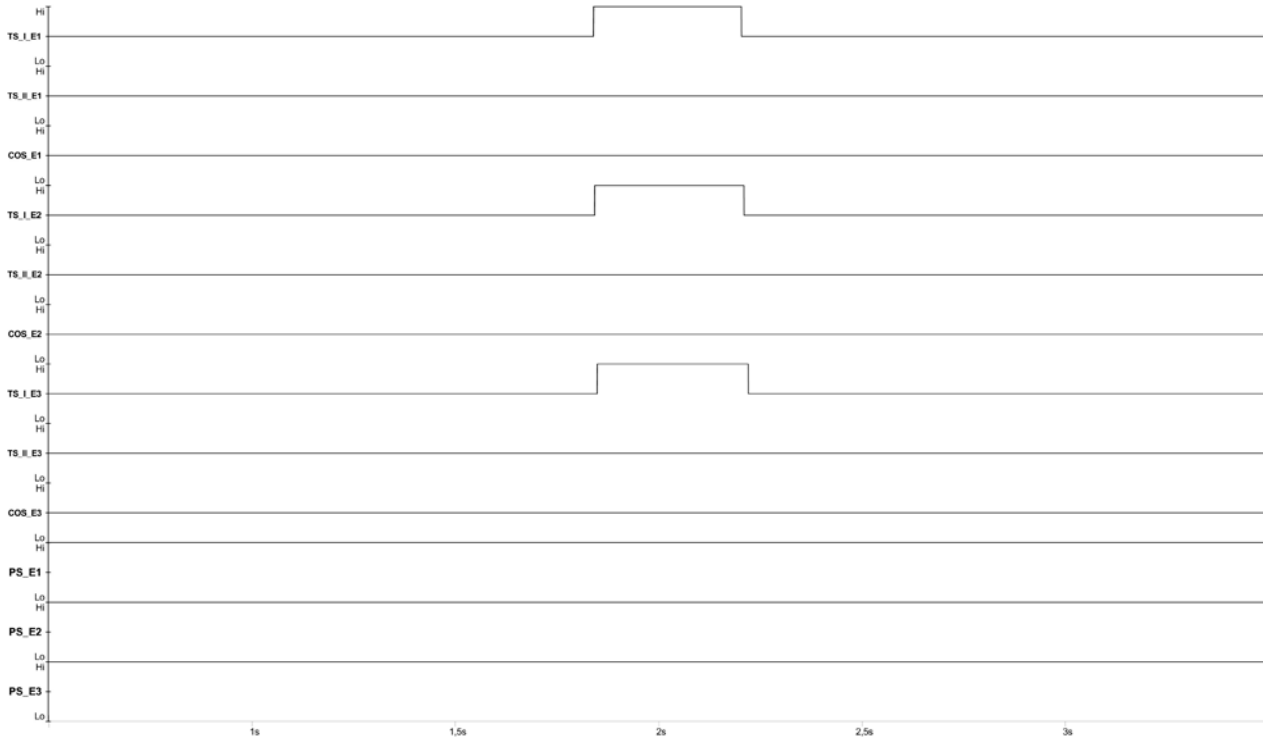

Fig. 6.10: Operation test at 105 °C (test sample 2) – Example of oscillogram at the end of the test.

TS_I, TS_II:	Tap selector arm 1, 2	COS:	Change-over selector
E1, E2, E3:	Contact planes 1, 2, 3	PS:	Potential switch

Picture 1: Test setup for the mechanical endurance test and the operation test at 105 °C.

Picture 2: Test setup for the mechanical endurance test and the operation test at 105 °C (heatable test vessel).