	Z a Δ P_k		
Tapping	1 (+ 5 %)	3 (0 %)	5 (- 5 %)
$Z_{measured}$ (Ω)	44.52	40.24	35.60
Z_{75} (Ω)	44.93	40.71	36.17
$\Delta P_{k\ measured}$ (W)	3 217.76	3 871.41	4 650.32
$\Delta P_{k\ 75}$ (W)	3 953.37	4 570.21	5 342.73

Tab. 2: Values of the short-circuit impedance and load loss.

Measurement of no-load loss and currents

Description

Measurement of no-load losses and currents was performed according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the tested transformer in temperature steady state.

Supply voltage was applied to LV terminals of the transformer; HV terminals were no-loaded. Supply voltage during the measurement was set to 90 %, 100 % and 110 % of rated voltage U_2.

Results

Measured values of no-load losses and currents are noted in **tab. 3** and **4**.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
Δ P_0 (W)	328.0	421.4	546,6

Tab. 3: Values of the no-load losses.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
I_0 (A)	1.0247	1.1057	1.4079

Tab. 4: Values of the no-load currents.

Temperature rise test

Description

Short-circuit method was used. Transformer was connected to the testing circuit according to the **fig. 1**. Lead-in copper cables 16 mm^2 on the side of HV terminals and copper pas with dimension ca. 800 mm^2 on the side of LV terminals were used. Frequency of power source was **f** = 50 Hz.

Mean temperature of the side of the HV and LV winding was determined by measuring of electrical resistance of the winding. Wiring is shown in **fig. 2**. The resistance was measured by Ohm´s method on both sides. At the end of the test, the time development of the resistance was recorded from the moment after switching circuits and electrical stabilization of the measuring circuit. The development was extrapolated to the moment when testing current was switched off.

Other temperatures were measured by thermocouples in connection with a measuring system. Oil temperature was measured in the oil sump at the top of the transformer. Side surface temperature was measured in eight points, four ones up and four ones down, close to corners of the transformer container. These values were used to calculate the temperature of the middle oil layer.

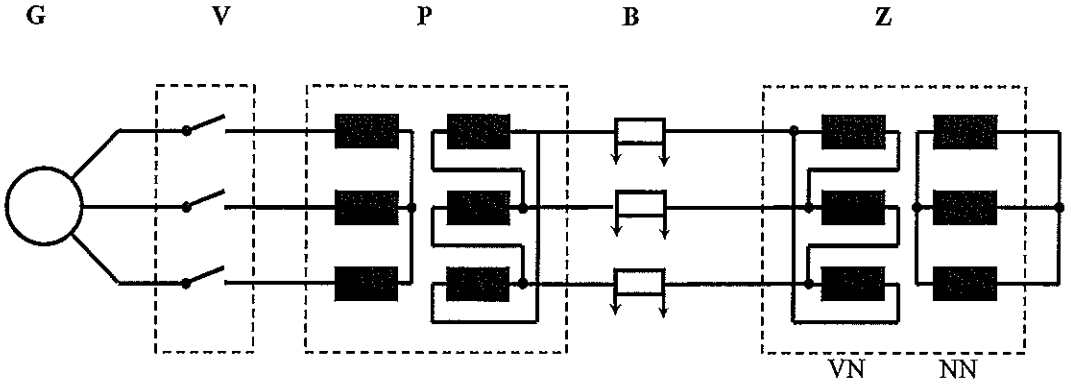
Ambient temperature was measured in four points, approximately 2 m distant from the transforme in one half of its height. Mean value was used to process results.

The test was divided into two parts. The first one was designated for measurement of the oil temperature rise above ambient. The second one was designated for measurement of the winding temperature rise above oil.

In the first part the transformer was loaded by a current (slightly higher than the nominal one) which generated the total losses (no-load losses plus short-circuit losses) 5 022,3 W in the transformer. The losses were measured on the HV terminals side. The losses were kept constant during the test, while the current slightly changed. When oil temperature became steady, the temperature of the middle oil layer was determined.

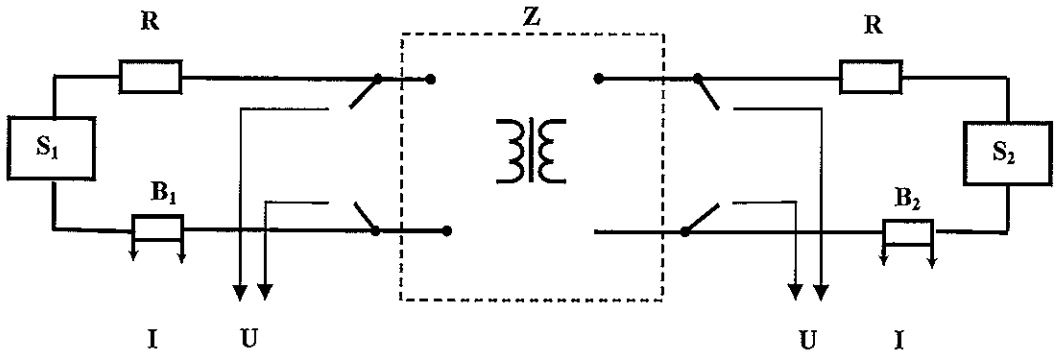
In the second part of the test the transformer was loaded by its nominal current **I** = 11.55 A for 1 hour. At the end the mean temperature of the winding and the temperature of the middle oil layer were determined.

Fig. 1: Measuring stand.



G	Generator 800 kVA,	**V**	generator breaker,
P	auxiliary transformer,	**B**	shunt for current measurement,
Z	tested transformer.		

Fig. 2: Testing power circuit for the temperature rise test.



Z	Tested transformer,	**S_1, S_2**	stabilized source of DC,
B_1, B_2	shunts for current measurement,	**R**	stabilizing resistors.

Fig. 5: Circuit for resistance measurement, arrows shows the connection to the measuring system.

Results

The test lasted 11.4 hours and it was finished according to Standard ČSN EN 60076-2 ed.2, Clause 7. Examples of time development of temperature are shown in **fig. 3**. Example of time development of interlaced and extrapolated resistance of the winding, connected to the LV and HV terminals, after the temperature rise test, are shown in **fig. 4**. Measured values of the resistance of the winding were extrapolated to the end of the temperature rise test. Recalculation between the resistances of the winding to the temperature was made by formula:

$$\Theta_2 = R_2 / R_1 \cdot (235 + \Theta_1) - 235$$

Θ_2 – temperature at the end of the test; Θ_1 – temperature before the test; R_2 – resistance of the winding at the end of the test; R_1 – resistance of the winding before the test.

Final results of temperature rise test are presented in **tab. 5.**

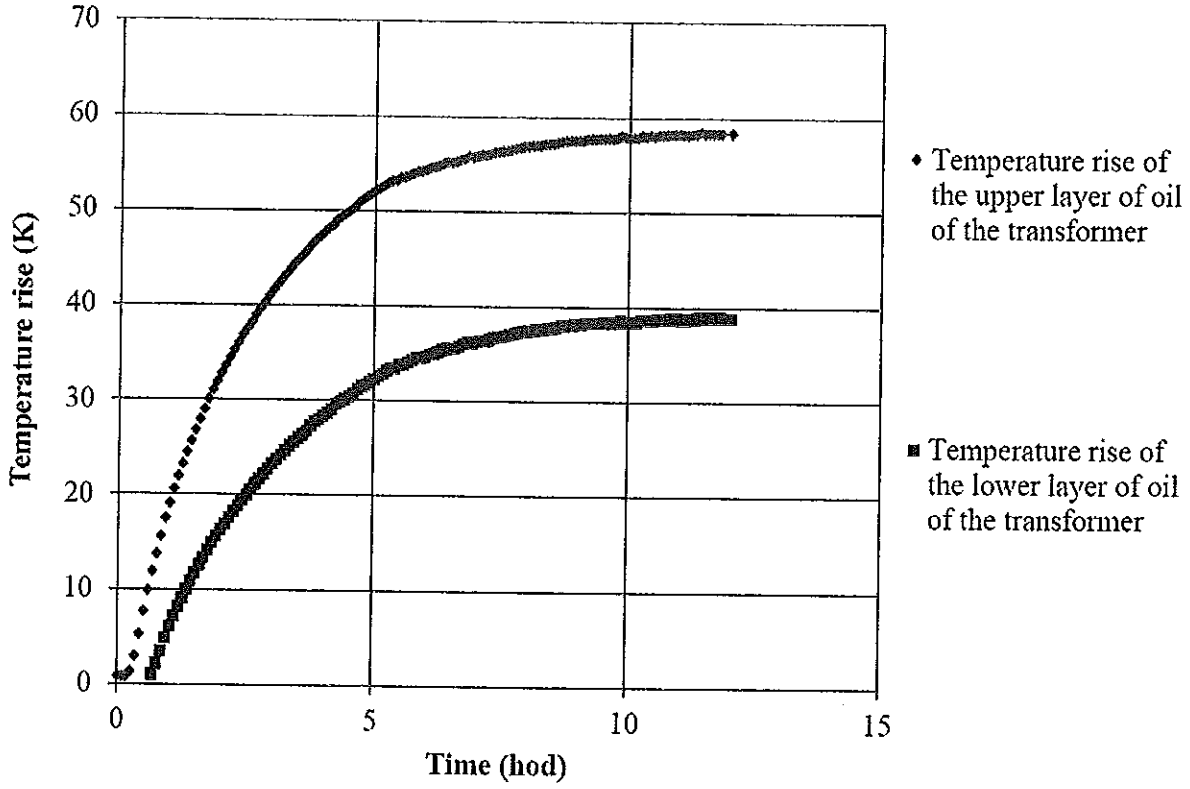


Fig. 3: Examples of temperature during the test.

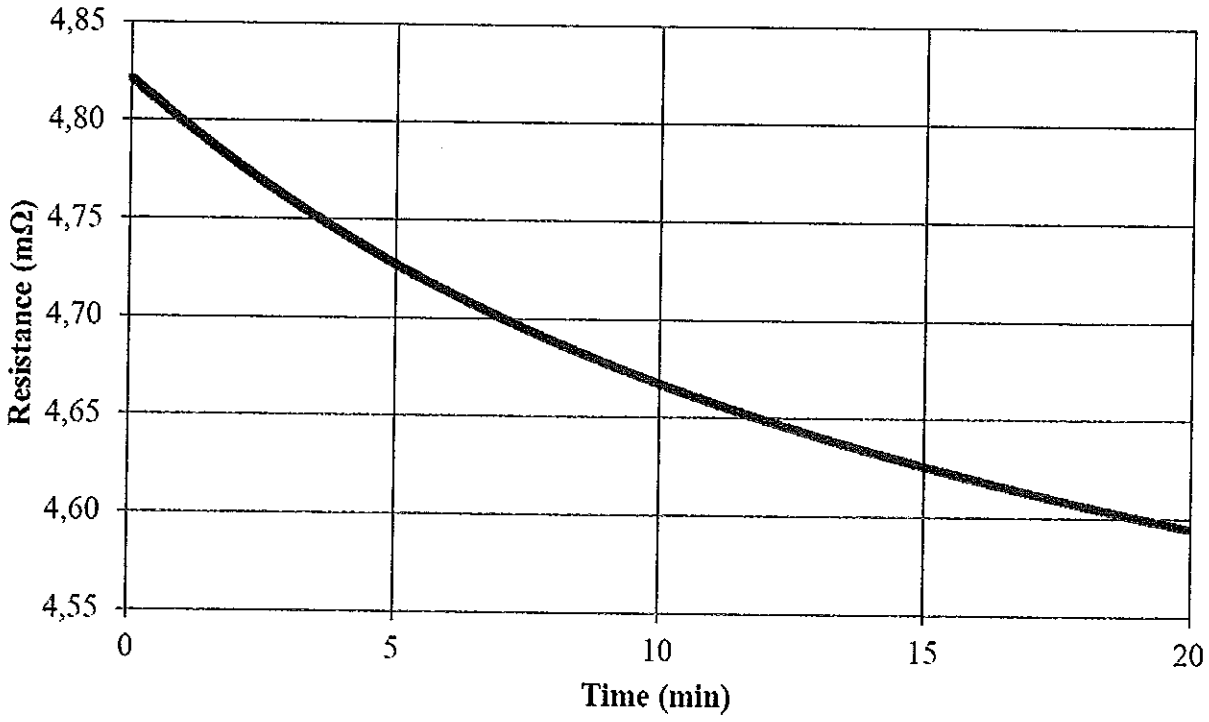


Fig. 4: Time development of interlaced and extrapolated resistances of the windings on the side of LV terminals after the temperature rise test.

		Temperature rise (K)	Limit (K)	Interpretation of test results
Temperature rise of the upper layer of oil		58.0	60	**Passed**
Middle temperature rise of the oil		48.3	--	--
Middle temperature rise of the winding	HV side	63.4	65	**Passed**
	LV side	64.8	65	**Passed**

Tab. 5: Temperature rise above ambient temperature, calculated by Standard ČSN EN 60076-2 ed.2. Uncertainty of temperature rise is maximally 1.2 K for oil measuring and 3.0 K for temperature rise test of winding. This uncertainty is calculated as product of standard uncertainty and coefficient "k", which corresponds to the interval of reliability circa 95%, which in case of standard distribution corresponds to coefficient k = 2.

Interpretation of the test results:

It is possible to certify according to the Standard ČSN EN 60076-2 ed.2, Clause. 7.11 „Uncertainties affecting the results of the temperature rise test", that the estimation of uncertainties should not be used for certification of specified limits gaining. Uncertainties should be used for information only.

Full wave lightning impulse test (LI)

Description

Full wave lightning impulse test was performed according to the Standard ČSN EN 60076-3 ed.2, Clause 13.2 at the principal tapping of the tested transformer with ratio 20/0.4 kV. The test was performed with standardized 1.2 μs $^{\pm 30\,\%}$/50 μs $^{\pm 20\,\%}$ lightning impulse of a negative polarity, **U** = 150 kV. The value of the testing voltage was chosen by the customer from the Standard ČSN EN 60076-3 ed.2, Table 2.

The test was performed for the following combination:

- 1 reference impulse (50 – 70% **U**),
- 3 impulses of 100 % **U** level.

This impulse combination was applied gradually to every phase terminal of the tested HV winding. The remaining phase terminals and the tank of the transformer were grounded. One additional measuring channel was used for the measurement of the current flowing from the remaining tw(interconnected phase terminal to the ground.

The lighting impulse test was performed under the following atmospheric conditions:

- atmospheric pressure: 99.33 kPa,
- temperature: 19.5 °C.

Results

The following test division and classification of each oscillogram is related to numeration, indicated under each following oscillogram **No. 1 – 13** in **figs 5-8:.**

Shape of wave – oscillogram 1.
Reference impulse – oscillograms 2 (phase 1U), 6 (phase 1V) and 10 (phase 1W).
Phase 1U – oscillograms 3, 4 and 5.
Phase 1V – oscillograms 7, 8 and 9.
Phase 1W – oscillograms 11, 12 and 13.

Interpretation of the test results:

It is evident (oscillograms in **fig. 5 - 8**) that the insulation of the tested transformer passed the lightning impulse tests (LI).

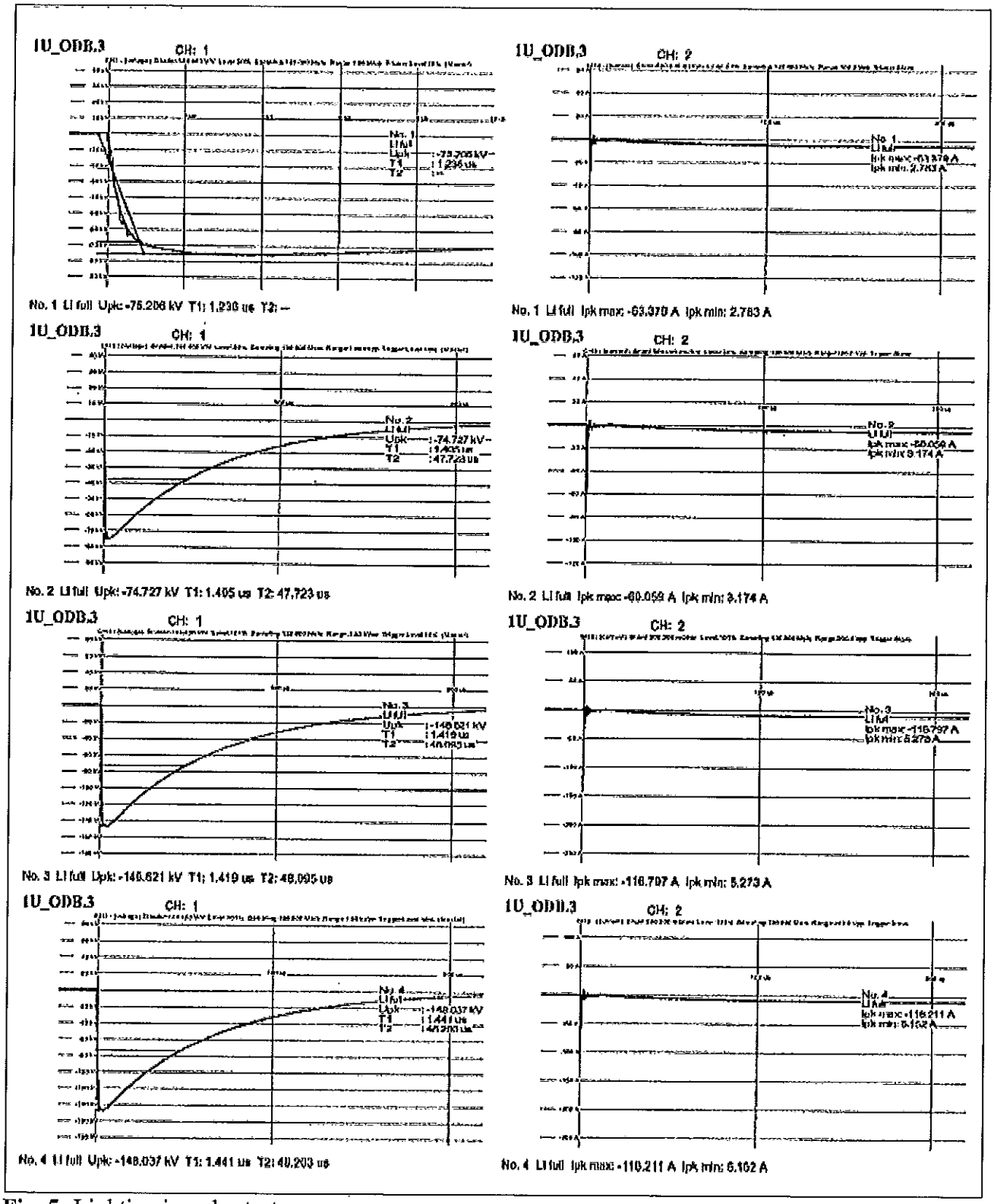


Fig. 5: Lighting impulse test.

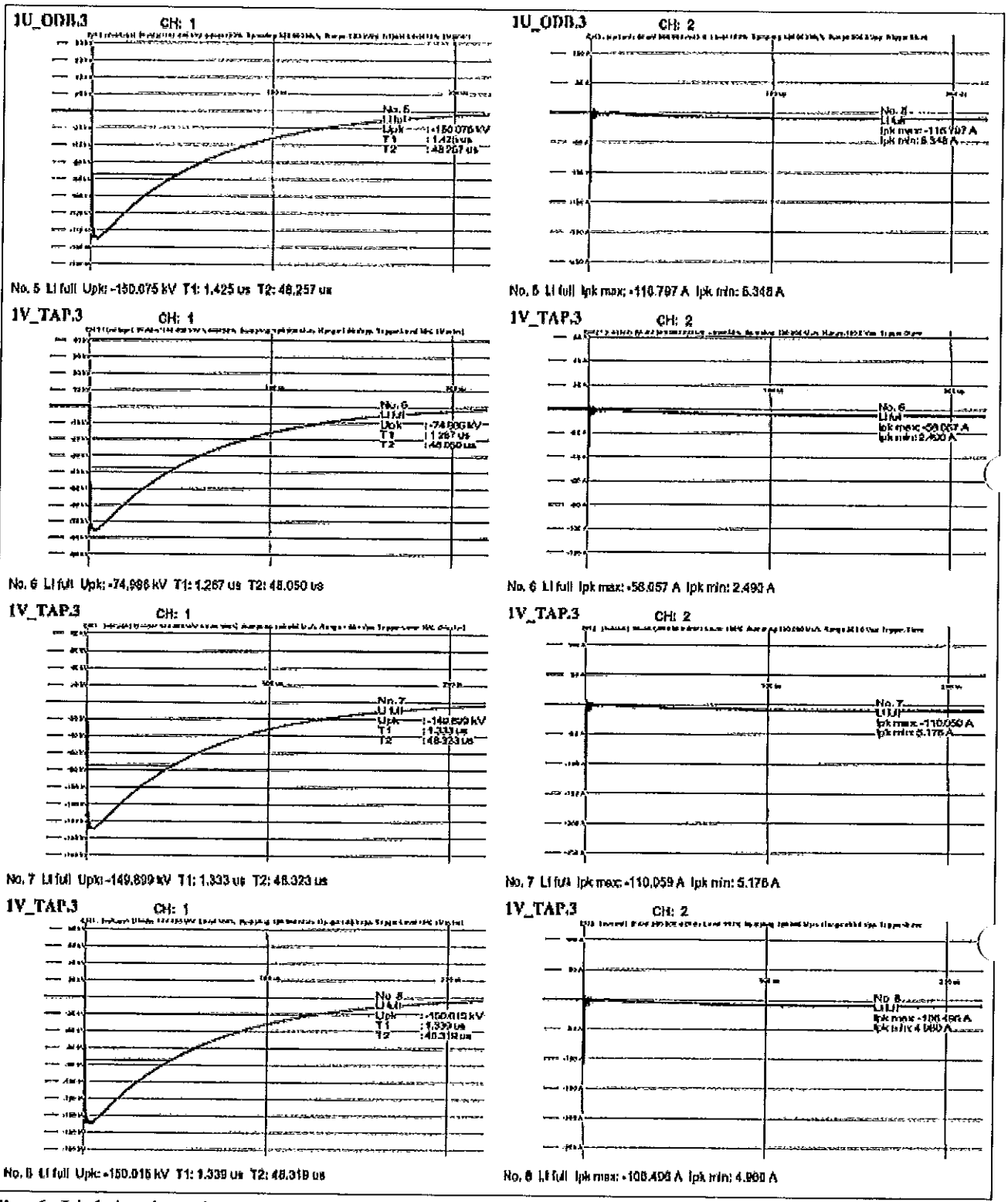


Fig. 6: Lighting impulse test.

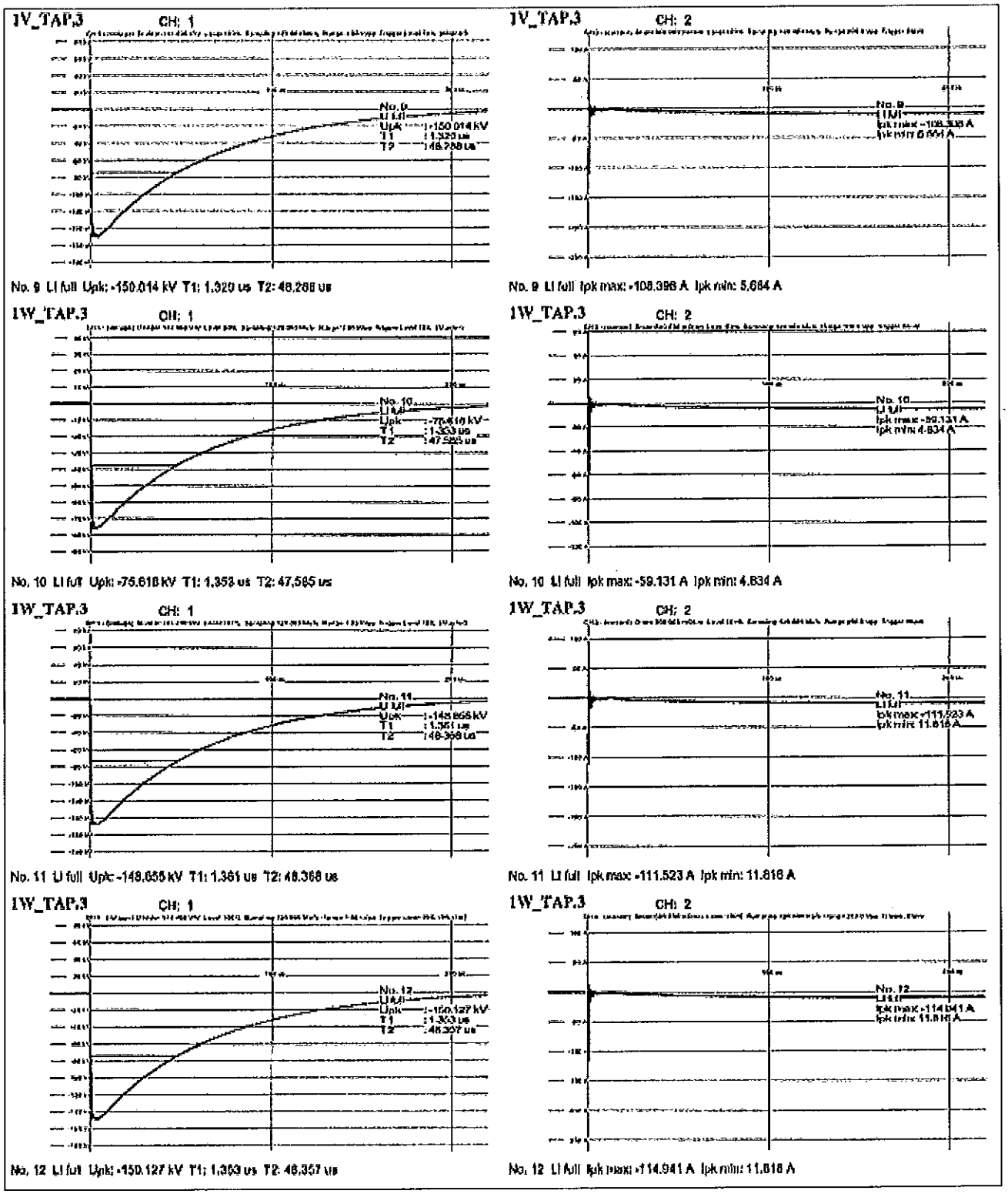


Fig. 7: Lighting impulse test.

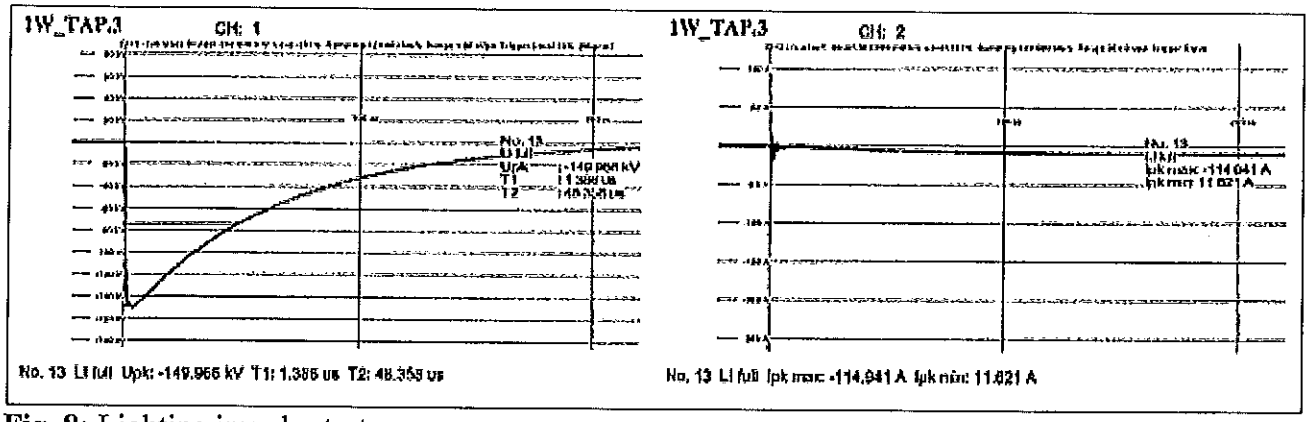


Fig. 8: Lighting impulse test.

NÁRODNÍ AKREDITAČNÍ ORGÁN

EA MLA Signatory
Český institut pro akreditaci, o.p.s.
Olšanská 54/3, 130 00 Praha 3

issues

according to section 16 of Act No 22/1997 Coll., on technical requirements for products, as amended

CERTIFICATE OF ACCREDITATION

No. 660 / 2015

ETD TRANSFORMÁTORY a.s.
with registered office Zborovská 54/22, 301 00 Plzeň, Company Registration No. 25137808

to the Testing Laboratory No. 1526
ELECTRICAL TESTING LABORATORY

Scope of accreditation:

Electrical and air-handling testing and measuring of industrial equipment to the extent as specified in the appendix to this Certificate.

This Certificate of Accreditation is a proof of Accreditation issued on the basis of assessment of fulfillment of the accreditation criteria in accordance with

ČSN EN ISO/IEC 17025:2005

In its activities performed within the scope and for the period of validity of this Certificate, the Body is entitled to refer to this Certificate, provided that the accreditation is not suspended and the Body meets the specified accreditation requirements in accordance with the relevant regulations applicable to the activity of an accredited Conformity Assessment Body.

This Certificate of Accreditation replaces, to the full extent, Certificate No.: 474/2014 of 15 July 2014, or any administrative acts building upon it.

The Certificate of Accreditation is valid until: 1 July 2018

Prague: 21 September 2015

Jiří Růžička
Director
Czech Accreditation Institute
Public Service Company

Methods used in testing are specified in the Quality Manual of the Electrical Testing Laboratory and satisfy the precision requirements according to the respective standards. The presented test results are in relation to the subject of these tests only. The Test Report may be reproduced only as a whole.
In case of discrepancies the Czech version of the Test Report takes precedence.

ETD TRANSFORMÁTORY a.s.
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L 1526

Total sheets: 13

Test Report

AP_EZ/2016/050/01/EN

Customer:	BEZ TRANSFORMÁTORY a.s. Rybničná 40 835 54 Bratislava
Tested object:	**Transformer TOHn 379/22, s.n. 0363137**
Test take over date:	September 23th , 2016
Test realization date:	September 29th , 2016
Test identification No.:	365-302-1624 **Evidentiary No:** 48/2016
Order No:	B06/4500006720

Testing methods, regulations:

ACCREDITED TESTS ACCORDING TO SOP_EZ/2, 4, 6 and 8:

ČSN EN 60076-1, Clause 11.2	Measurement of winding resistance
ČSN EN 60076-1, Clause 11.4	Measurement of short-circuit impedance and load loss
ČSN EN 60076-1, Clause 11.5	Measurement of no-load loss and current
ČSN EN 60076-2 ed.2	Power transformer – Part 2: Temperature rise for liquid-immersed transformers
ČSN EN 60076-3 ed.2, Clause 13.2	Full wave lightning impulse test (LI)

Test results: In the text.

Enclosures: --

In Plzeň, 30th September 2016

Petr Šíma
Electrical Testing Laboratory Director

Test Report is issued in 3 copies – 2 are obtained by the customer and 1 is kept in the Laboratory.
Test Report is issued for the customer in electronic form too.

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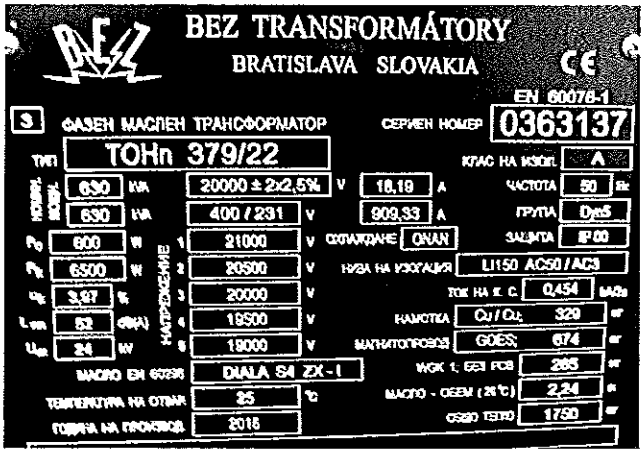
Description 8
Results 8

Tested object

Oil-immersed transformer TOHn 379/22.



Performed tests

Routine tests:

- Measurement of winding resistance according to the Standard ČSN EN 60076-1, Clause 11.2. The test was carried out at tappings 1, 3 and 5 of the tested transformer.
- Measurement of short-circuit impedance and load loss according to the Standard ČSN EN 60076-1, Clause 11.4. The test was carried out at tappings 1, 3 and 5 of the tested transformer.
- Measurement of no-load loss and current according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the tested transformer.

Type tests:

- Temperature rise test according to the Standard ČSN EN 60076-2 ed.2 at tapping 3 of the tested transformer with ratio 20/0.4 kV.
- Full wave lightning impulse test (LI) of the tested transformer according to the Standard ČSN EN 60076-3 ed.2, Clause 13.2. Test was carried out at HV side with negative wave 150 kV.

Used apparatuses

Name	Type	Filing No.
Digital multimeter	Fluke 189	PMMm 263
Digital multimeter	Fluke 179	PMMm 269
Digital oscilloscope	AT DSO7034A	PMMo 265
Digital oscilloscope	Keysight DSO-X 4034A	PMMo 270
Isolating converters	BB3652	PMMp 254
Mercury thermometer	from 0°C to 50°C	PMMt 239
Digital thermometer	GMH 3710	PMMt 268
Current transformer	ABB Petercem EA100	PMTr 92
Current transformer	ABB Petercem EA100	PMTr 93
Current transformer	ABB Petercem EA100	PMTr 94
Three-phase power analyzer	D6100	PMWa 19
Power analyzer	Norma 5000	PMWa 27
Impulse Analyzing System	HiAS 743	176736

Measurement of winding resistance

Description

The measurement of winding resistance was performed according to the Standard ČSN EN 60076-1, Clause 11.2.3. Measurement was carried out at tappings 1, 3 and 5 of the tested transformer in temperature steady state.

Winding resistances each of above mentioned tappings were measured with DC current, with Ohm's method, between terminals of each phase on HV side of transformer and between node and terminal of respective phase on LV side of tested transformer. The mean temperature of cooling liquid (temperature of transformer winding) was measured during the test. Temperature was 22.4 °C. Resulting value of the resistance was recalculated to 75 °C.

Results

Resistances of transformer winding are noted in **Tab. 1.**

Side of transformer	Tap	Terminal	Before type and special tests	
			$R_{measured}$ (Ω)	R_{75} (Ω)
HV	1 (+ 5 %)	1U – 1V	5.413261123	6.519467553
		1U – 1W	5.419628383	6.527135970
		1V – 1W	5.430576016	6.540320765
	3 (0 %)	1U – 1V	5.125074746	6.172389943
		1U – 1W	5.133326675	6.182328164
		1V – 1W	5.142458309	6.193325858
	5 (- 5 %)	1U – 1V	4.840437458	5.829586682
		1U – 1W	4.847244409	5.837784642
		1V – 1W	4.857349674	5.849954930
LV		2n – 2u	0.001054948	0.001270528
		2n – 2v	0.001087017	0.001301563
		2n – 2w	0.001103326	0.001328792

Tab. 1: Resistances of transformer winding.

Measurement of short-circuit impedance and load loss

Description

Measurement of short-circuit impedance and load loss was performed according to the Standard ČSN EN 60076-1, Clause 11.4. The test was carried out at tappings 1, 3 and 5 of the tested transformer in temperature steady state.

Voltage was applied to HV terminals of the transformer, LV terminals were short circuited. Supply current of 50 Hz was ca. 10 A. Temperature was 22.7 °C.

Measured values of short-circuit impedance and load loss were corrected for the reference temperature 75 °C.

Results

Measured values of short-circuit impedance and load loss are noted in **Tab. 2.**

	Z a Δ P_k		
Tapping	1 (+ 5 %)	3 (0 %)	5 (- 5 %)
$Z_{measured}$ (Ω)	28.34	25.14	22.31
Z_{75} (Ω)	28.54	25.38	22.60
Δ $P_{k\ measured}$ (W)	4 619.76	5 524.28	6 631.54
Δ $P_{k\ 75}$ (W)	5 637.77	6 495.30	7 594.04

Tab. 2: Values of the short-circuit impedance and load loss.

Measurement of no-load loss and currents

Description

Measurement of no-load losses and currents was performed according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the tested transformer in temperature steady state.

Supply voltage was applied to LV terminals of the transformer; HV terminals were no-loaded. Supply voltage during the measurement was set to 90 %, 100 % and 110 % of rated voltage U_2.

Results

Measured values of no-load losses and currents are noted in **tab. 3** and **4**.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
Δ P_0 (W)	448.2	586.2	813.1

Tab. 3: Values of the no-load losses.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
I_0 (A)	1.0504	1.6423	6.5117

Tab. 4: Values of the no-load currents.

Temperature rise test

Description

Short-circuit method was used. Transformer was connected to the testing circuit according to the **fig. 1**. Lead-in copper cables 16 mm^2 on the side of HV terminals and copper pas with dimension ca. 800 mm^2 on the side of LV terminals were used. Frequency of power source was **f** = 50 Hz.

Mean temperature of the side of the HV and LV winding was determined by measuring of electrical resistance of the winding. Wiring is shown in **fig. 2**. The resistance was measured by Ohm's method on both sides. At the end of the test, the time development of the resistance was recorded from the moment after switching circuits and electrical stabilization of the measuring circuit. The development was extrapolated to the moment when testing current was switched off.

Other temperatures were measured by thermocouples in connection with a measuring system. Oil temperature was measured in the oil sump at the top of the transformer. Side surface temperature was measured in eight points, four ones up and four ones down, close to corners of the transformer container. These values were used to calculate the temperature of the middle oil layer.

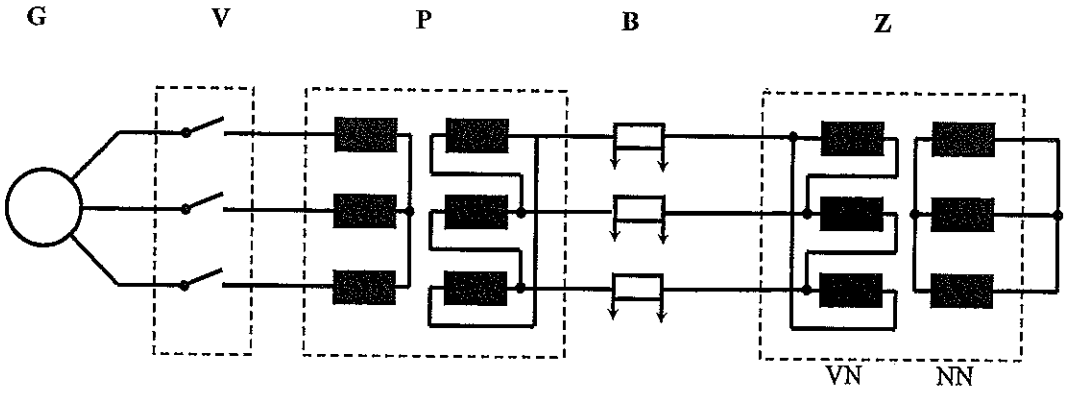
Ambient temperature was measured in four points, approximately 2 m distant from the transforme in one half of its height. Mean value was used to process results.

The test was divided into two parts. The first one was designated for measurement of the oil temperature rise above ambient. The second one was designated for measurement of the winding temperature rise above oil.

In the first part the transformer was loaded by a current (slightly higher than the nominal one) which generated the total losses (no-load losses plus short-circuit losses) 7 038,3 W in the transformer. The losses were measured on the HV terminals side. The losses were kept constant during the test, while the current slightly changed. When oil temperature became steady, the temperature of the middle oil layer was determined.

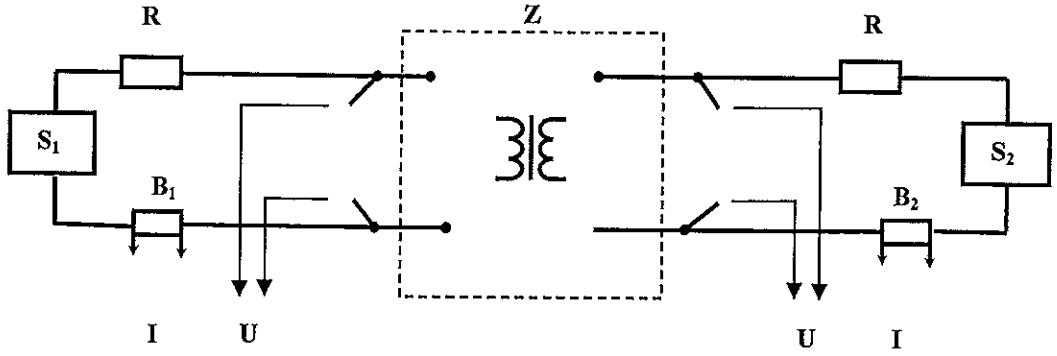
In the second part of the test the transformer was loaded by its nominal current **I** = 18.19 A for 1 hour. At the end the mean temperature of the winding and the temperature of the middle oil layer were determined.

Fig. 1: Measuring stand.



G	Generator 800 kVA,	**V**	generator breaker,
P	auxiliary transformer,	**B**	shunt for current measurement,
Z	tested transformer.		

Fig. 2: Testing power circuit for the temperature rise test.



Z	Tested transformer,	S_1, S_2	stabilized source of DC,
B_1, B_2	shunts for current measurement,	**R**	stabilizing resistors.

Fig. 5: Circuit for resistance measurement, arrows shows the connection to the measuring system.

Results

The test lasted 11.4 hours and it was finished according to Standard ČSN EN 60076-2 ed.2, Clause 7. Examples of time development of temperature are shown in **fig. 3**. Example of time development of interlaced and extrapolated resistance of the winding, connected to the LV and HV terminals, after the temperature rise test, are shown in **fig. 4**. Measured values of the resistance of the winding were extrapolated to the end of the temperature rise test. Recalculation between the resistances of the winding to the temperature was made by formula:

$$\Theta_2 = R_2 / R_1 \cdot (235 + \Theta_1) - 235$$

Θ_2 – temperature at the end of the test; Θ_1 – temperature before the test; R_2 – resistance of the winding at the end of the test; R_1 – resistance of the winding before the test.

Final results of temperature rise test are presented in **tab. 5.**

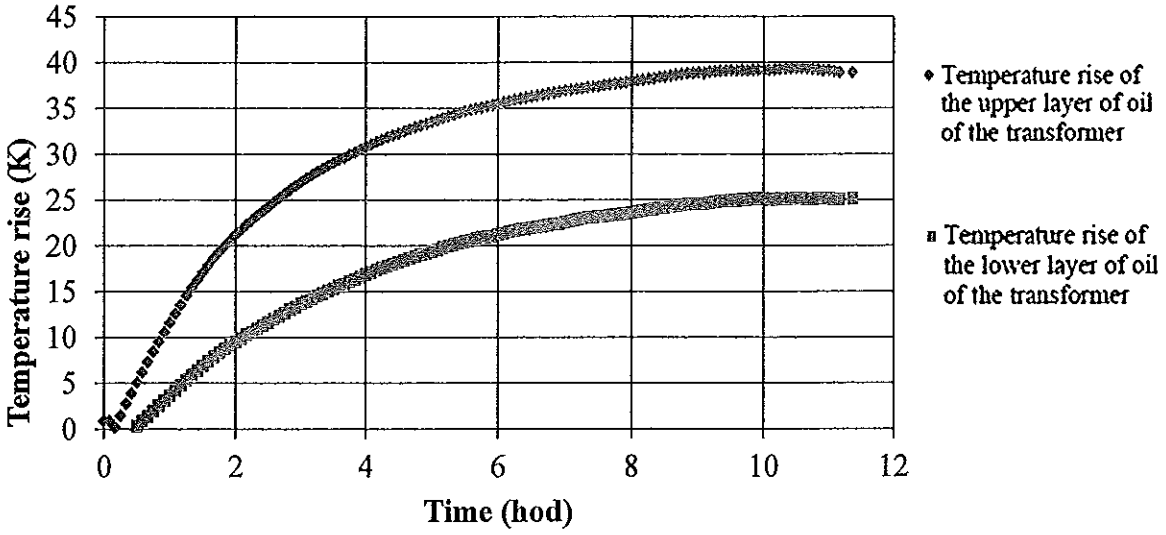


Fig. 3: Examples of temperature during the test.

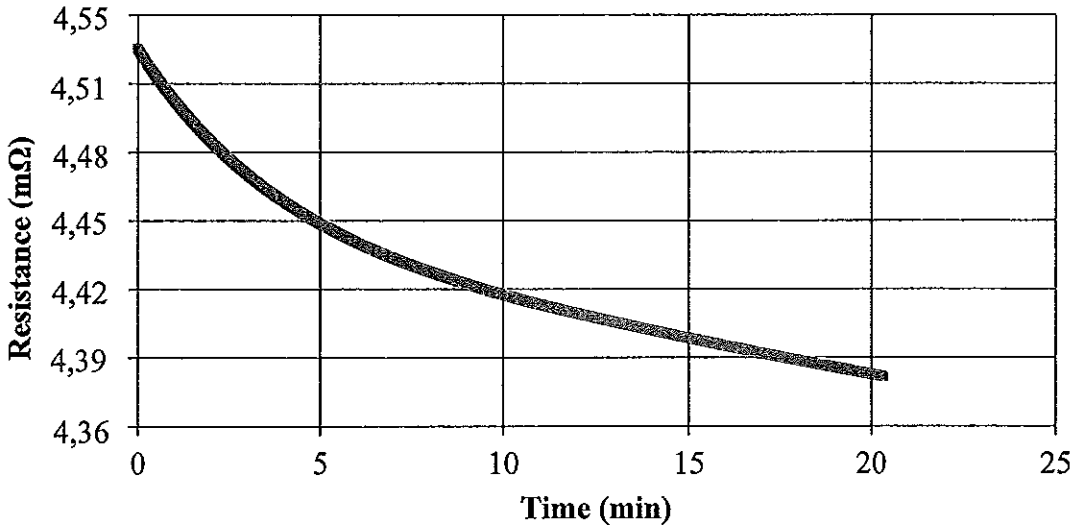


Fig. 4: Time development of interlaced and extrapolated resistances of the windings on the side of LV terminals after the temperature rise test.

		Temperature rise (K)	Limit (K)	Interpretation of test results
Temperature rise of the upper layer of oil		39.3	60	**Passed**
Middle temperature rise of the oil		32.15	--	--
Middle temperature rise of the winding	HV side	64.2	65	**Passed**
	LV side	63.6	65	**Passed**

Tab. 5: Temperature rise above ambient temperature, calculated by Standard ČSN EN 60076-2 ed.2. Uncertainty of temperature rise is maximally 1.2 K for oil measuring and 3.0 K for temperature rise test of winding. This uncertainty is calculated as product of standard uncertainty and coefficient "k", which corresponds to the interval of reliability circa 95%, which in case of standard distribution corresponds to coefficient k = 2.

Interpretation of the test results:

It is possible to certify according to the Standard ČSN EN 60076-2 ed.2, Clause. 7.11 „Uncertainties affecting the results of the temperature rise test", that the estimation of uncertainties should not be used for certification of specified limits gaining. Uncertainties should be used for information only.

Full wave lightning impulse test (LI)

Description

Full wave lightning impulse test was performed according to the Standard ČSN EN 60076-3 ed.2, Clause 13.2 at the principal tapping of the tested transformer with ratio 20/0.4 kV. The test was performed with standardized 1.2 μs $^{\pm 30\ \%}$/50 μs $^{\pm 20\ \%}$ lightning impulse of a negative polarity, **U** = 150 kV. The value of the testing voltage was chosen by the customer from the Standard ČSN EN 60076-3 ed.2, Table 2.

The test was performed for the following combination:

- 1 reference impulse (50 – 70% **U**),
- 3 impulses of 100 % **U** level.

This impulse combination was applied gradually to every phase terminal of the tested HV winding. The remaining phase terminals and the tank of the transformer were grounded. One additional measuring channel was used for the measurement of the current flowing from the remaining two interconnected phase terminal to the ground.

The lighting impulse test was performed under the following atmospheric conditions:

- atmospheric pressure: 100.33 kPa,
- temperature: 18.7 °C.

Results

The following test division and classification of each oscillogram is related to numeration, indicated under each following oscillogram **No. 1 – 13** in **figs 5-8:.**

Shape of wave – oscillogram 1.
Reference impulse – oscillograms 2 (phase 1U), 6 (phase 1V) and 10 (phase 1W).
Phase 1U – oscillograms 3, 4 and 5.
Phase 1V – oscillograms 7, 8 and 9.
Phase 1W – oscillograms 11, 12 and 13.

Interpretation of the test results:

It is evident (oscillograms in **fig. 5 - 8**) that the insulation of the tested transformer passed the lightning impulse tests (LI).

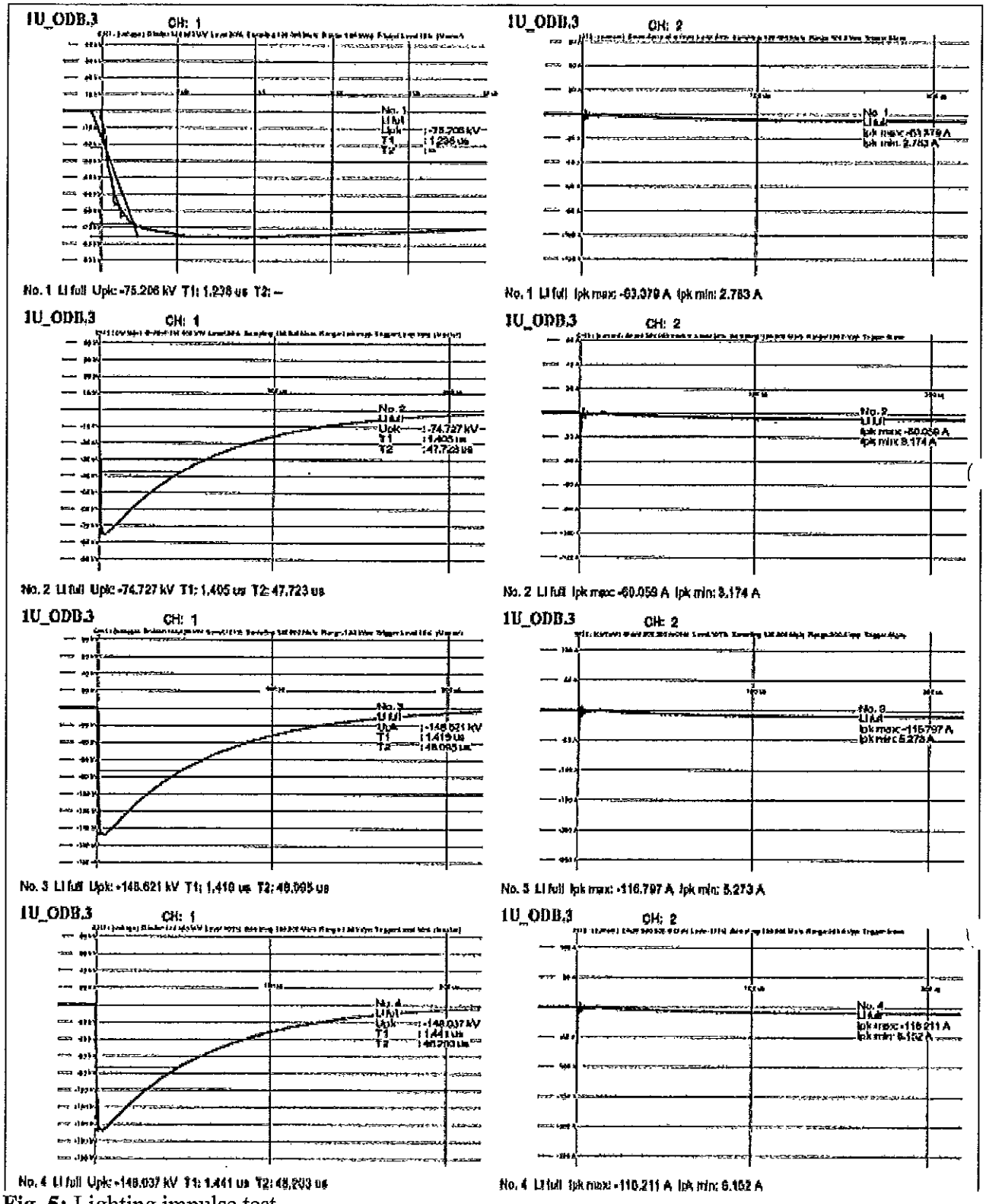


Fig. 5: Lighting impulse test.

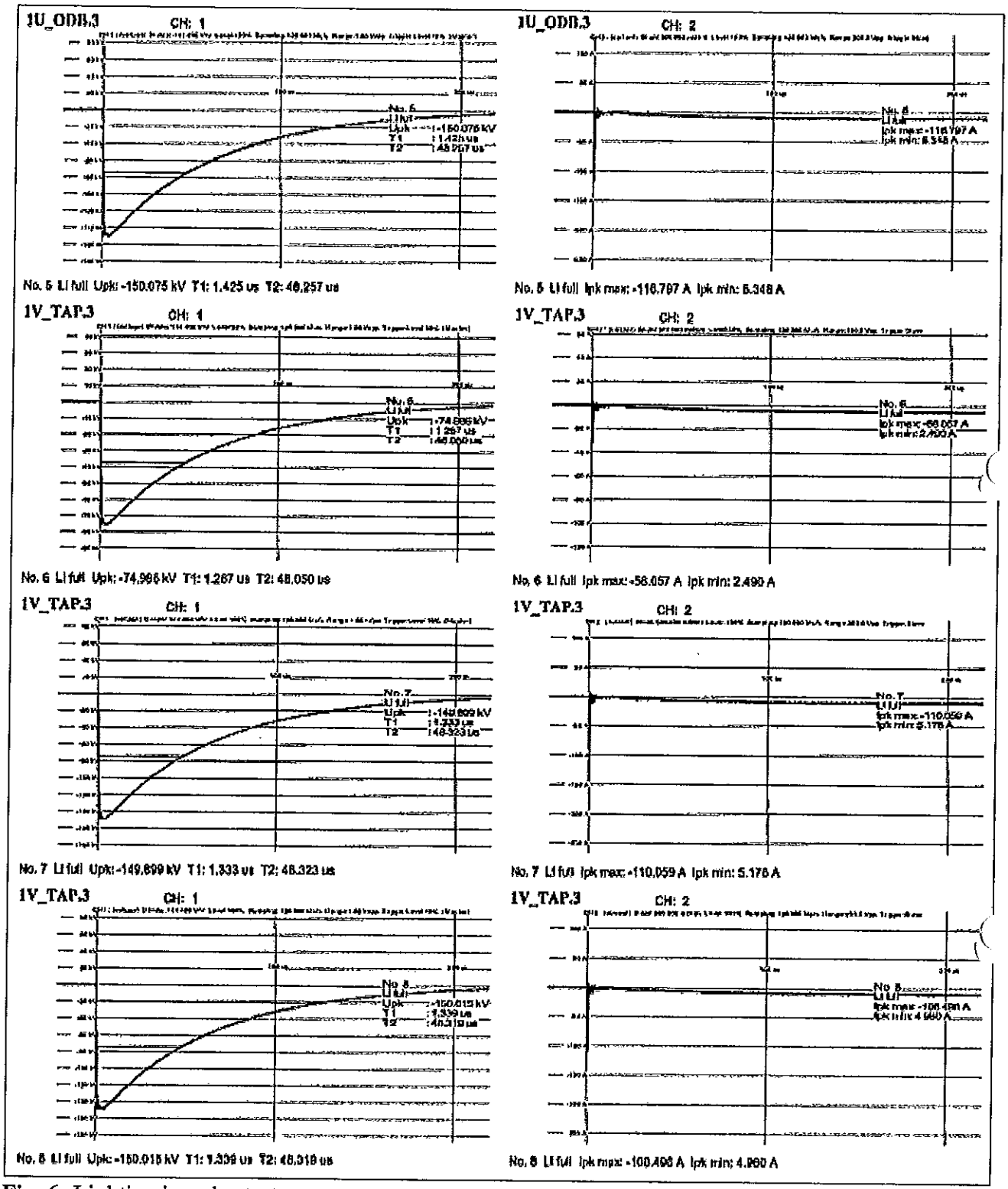


Fig. 6: Lighting impulse test.

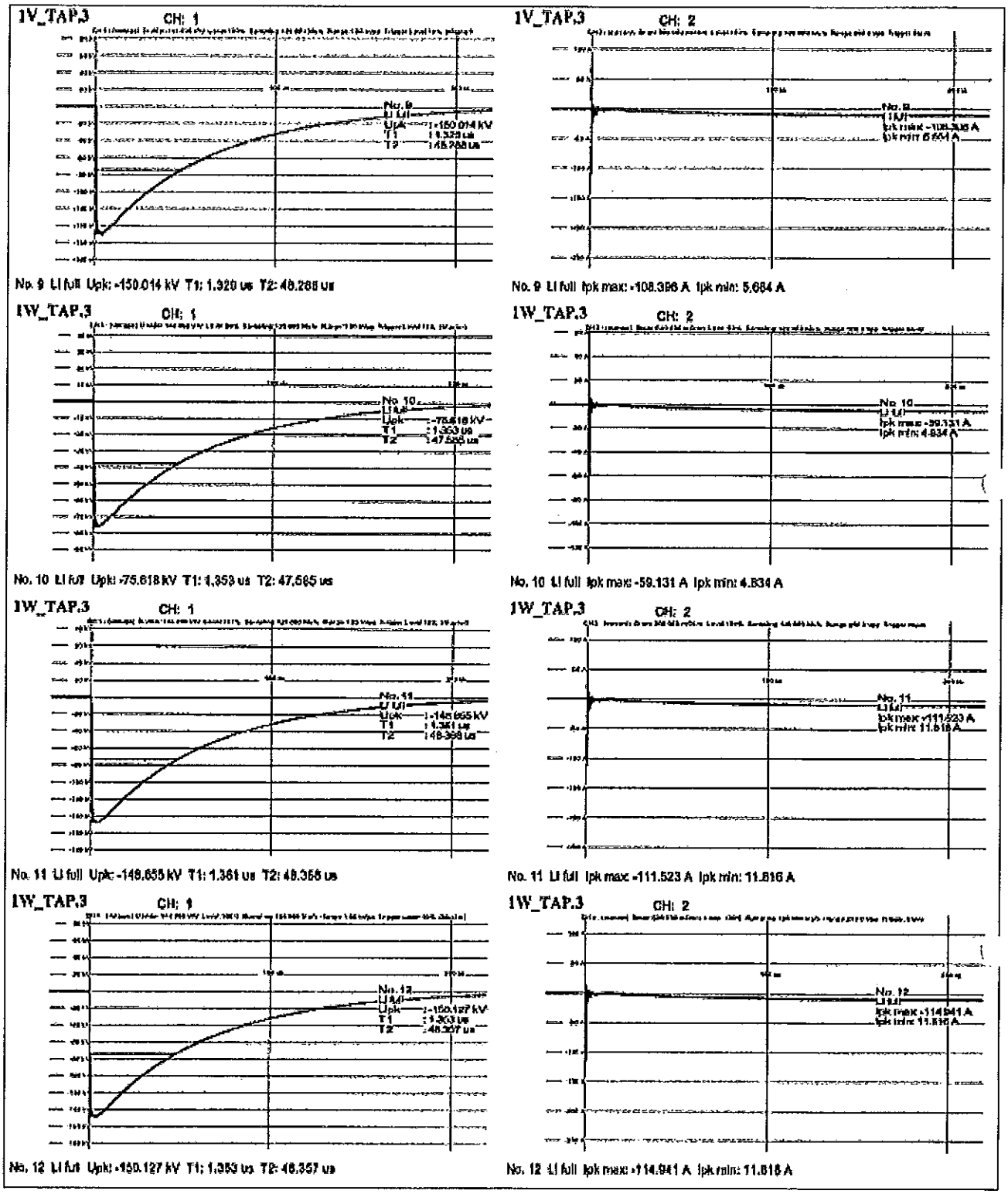


Fig. 7: Lighting impulse test.

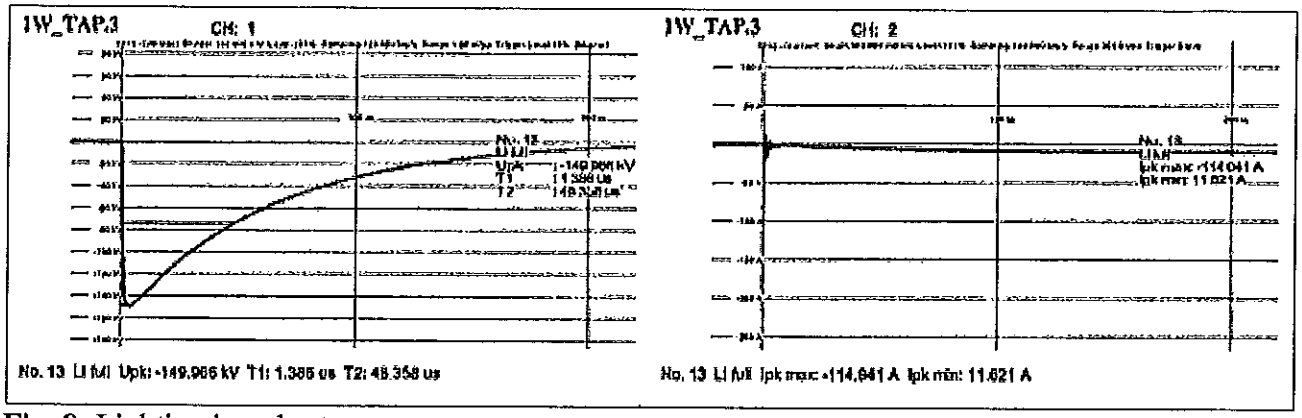


Fig. 8: Lighting impulse test.

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EA MLA Signatory
Český institut pro akreditaci, o.p.s.
Olšanská 54/3, 130 00 Praha 3

issues

according to section 16 of Act No 22/1997 Coll., on technical requirements for products, as amended

CERTIFICATE OF ACCREDITATION

No. 660 / 2015

ETD TRANSFORMÁTORY a.s.
with registered office Zborovská 54/22, 301 00 Plzeň, Company Registration No. 25137808

to the Testing Laboratory No. 1526
ELECTRICAL TESTING LABORATORY

Scope of accreditation:

Electrical and air-handling testing and measuring of industrial equipment to the extent as specified in the appendix to this Certificate.

This Certificate of Accreditation is a proof of Accreditation issued on the basis of assessment of fulfillment of the accreditation criteria in accordance with

ČSN EN ISO/IEC 17025:2005

In its activities performed within the scope and for the period of validity of this Certificate, the Body is entitled to refer to this Certificate, provided that the accreditation is not suspended and the Body meets the specified accreditation requirements in accordance with the relevant regulations applicable to the activity of an accredited Conformity Assessment Body.

This Certificate of Accreditation replaces, to the full extent, Certificate No.: 474/2014 of 15 July 2014, or any administrative acts building upon it

The Certificate of Accreditation is valid until: **1 July 2018**

Prague: 21 September 2015

Jiří Růžička
Director
Czech Accreditation Institute
Public Service Company

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In case of discrepancies the Czech version of the Test Report takes precedence.

ETD TRANSFORMÁTORY a.s.
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L 1526

Total sheets: 13

Test Report

AP_EZ/2016/051/01/EN

Customer:	BEZ TRANSFORMÁTORY a.s. Rybničná 40 835 54 Bratislava		
Tested object:	**Transformer TOHn 389/22, s.n. 0361831**		
Test take over date:	September 23th, 2016		
Test realization date:	September 30th, 2016		
Test identification No.:	365-302-1624	**Evidentiary No:**	48/2016
Order No:	B06/4500006720		

Testing methods, regulations:

ACCREDITED TESTS ACCORDING TO SOP_EZ/2, 4, 6 and 8:

ČSN EN 60076-1, Clause 11.2	Measurement of winding resistance
ČSN EN 60076-1, Clause 11.4	Measurement of short-circuit impedance and load loss
ČSN EN 60076-1, Clause 11.5	Measurement of no-load loss and current
ČSN EN 60076-2 ed.2	Power transformer – Part 2: Temperature rise for liquid-immersed transformers
ČSN EN 60076-3 ed.2, Clause 13.2	Full wave lightning impulse test (LI)

Test results: In the text.

Enclosures: --

In Plzeň, 30th September 2016

Petr Šíma
Electrical Testing Laboratory Director

Test Report is issued in 3 copies – 2 are obtained by the customer and 1 is kept in the Laboratory.
Test Report is issued for the customer in electronic form too.

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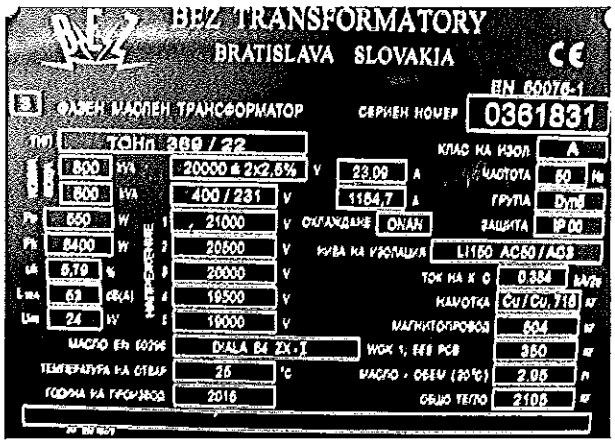
Tested object

Oil-immersed transformer TOHn 389/22.



Performed tests

Routine tests:

- Measurement of winding resistance according to the Standard ČSN EN 60076-1, Clause 11.2. The test was carried out at tappings 1, 3 and 5 of the tested transformer.
- Measurement of short-circuit impedance and load loss according to the Standard ČSN EN 60076-1, Clause 11.4. The test was carried out at tappings 1, 3 and 5 of the tested transformer.
- Measurement of no-load loss and current according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the tested transformer.

Type tests:

- Temperature rise test according to the Standard ČSN EN 60076-2 ed.2 at tapping 3 of the tested transformer with ratio 20/0.4 kV.
- Full wave lightning impulse test (LI) of the tested transformer according to the Standard ČSN EN 60076-3 ed.2, Clause 13.2. Test was carried out at HV side with negative wave 150 kV.

Used apparatuses

Name	Type	Filing No.
Digital multimeter	Fluke 189	PMMm 263
Digital multimeter	Fluke 179	PMMm 269
Digital oscilloscope	AT DSO7034A	PMMo 265
Digital oscilloscope	Keysight DSO-X 4034A	PMMo 270
Isolating converters	BB3652	PMMp 254
Mercury thermometer	from 0°C to 50°C	PMMt 239
Digital thermometer	GMH 3710	PMMt 268
Current transformer	ABB Petercem EA100	PMTr 92
Current transformer	ABB Petercem EA100	PMTr 93
Current transformer	ABB Petercem EA100	PMTr 94
Three-phase power analyzer	D6100	PMWa 19
Power analyzer	Norma 5000	PMWa 27
Impulse Analyzing System	HiAS 743	176736

Measurement of winding resistance

Description

The measurement of winding resistance was performed according to the Standard ČSN EN 60076-1, Clause 11.2.3. Measurement was carried out at tappings 1, 3 and 5 of the tested transformer in temperature steady state.

Winding resistances each of above mentioned tappings were measured with DC current, with Ohm's method, between terminals of each phase on HV side of transformer and between node and terminal of respective phase on LV side of tested transformer. The mean temperature of cooling liquid (temperature of transformer winding) was measured during the test. Temperature was 22.5 °C. Resulting value of the resistance was recalculated to 75 °C.

Results

Resistances of transformer winding are noted in **Tab. 1.**

Side of transformer	Tap	Terminal	Before type and special tests	
			$R_{measured}$ (Ω)	R_{75} (Ω)
HV	1 (+ 5 %)	1U – 1V	4.130217695	4.972300915
		1U – 1W	4.122274221	4.962737897
		1V – 1W	4.131014447	4.973260110
	3 (0 %)	1U – 1V	3.907538807	4.704221476
		1U – 1W	3.898721044	4.693605917
		1V – 1W	3.905860784	4.702201332
	5 (- 5 %)	1U – 1V	3.686047671	4.437571954
		1U – 1W	3.678689180	4.428713187
		1V – 1W	3.686406004	4.438003344
LV		2n – 2u	0.000788773	0.000949591
		2n – 2v	0.000777999	0.000936620
		2n – 2w	0.000799017	0.000961923

Tab. 1: Resistances of transformer winding.

Measurement of short-circuit impedance and load loss

Description

Measurement of short-circuit impedance and load loss was performed according to the Standard ČSN EN 60076-1, Clause 11.4. The test was carried out at tappings 1, 3 and 5 of the tested transformer in temperature steady state.

Voltage was applied to HV terminals of the transformer, LV terminals were short circuited. Supply current of 50 Hz was ca. 13 A. Temperature was 22.7 °C.

Measured values of short-circuit impedance and load loss were corrected for the reference temperature 75 °C.

Results

Measured values of short-circuit impedance and load loss are noted in **Tab. 2.**

	Z a ΔP_k		
Tapping	1 (+ 5 %)	3 (0 %)	5 (- 5 %)
$Z_{measured}$ (Ω)	32.70	28.82	25.49
Z_{75} (Ω)	32.79	28.94	25.62
$\Delta P_{k\ measured}$ (W)	5 745.95	6 885.53	8 291.65
$\Delta P_{k\ 75}$ (W)	6 900.20	7 998.12	9 372.92

Tab. 2: Values of the short-circuit impedance and load loss.

Measurement of no-load loss and currents

Description

Measurement of no-load losses and currents was performed according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the tested transformer in temperature steady state.

Supply voltage was applied to LV terminals of the transformer; HV terminals were no-loaded. Supply voltage during the measurement was set to 90 %, 100 % and 110 % of rated voltage U_2.

Results

Measured values of no-load losses and currents are noted in **tab. 3** and **4**.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
ΔP_0 (W)	478.1	643.8	869.4

Tab. 3: Values of the no-load losses.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
I_0 (A)	1.0976	1.7373	6.5700

Tab. 4: Values of the no-load currents.

Temperature rise test

Description

Short-circuit method was used. Transformer was connected to the testing circuit according to the **fig. 1**. Lead-in copper cables 16 mm^2 on the side of HV terminals and copper pas with dimension ca. 800 mm^2 on the side of LV terminals were used. Frequency of power source was **f** = 50 Hz.

Mean temperature of the side of the HV and LV winding was determined by measuring of electrical resistance of the winding. Wiring is shown in **fig. 2**. The resistance was measured by Ohm´s method on both sides. At the end of the test, the time development of the resistance was recorded from the moment after switching circuits and electrical stabilization of the measuring circuit. The development was extrapolated to the moment when testing current was switched off.

Other temperatures were measured by thermocouples in connection with a measuring system. Oil temperature was measured in the oil sump at the top of the transformer. Side surface temperature was measured in eight points, four ones up and four ones down, close to corners of the transformer container. These values were used to calculate the temperature of the middle oil layer.

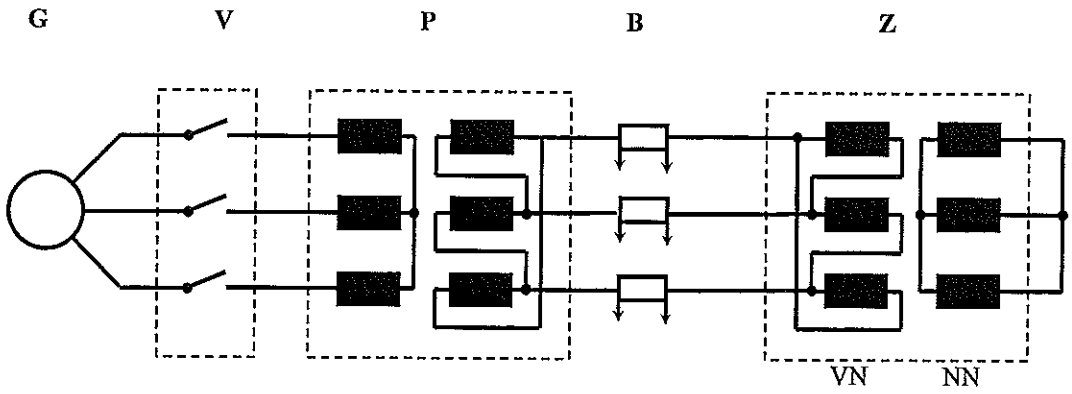
Ambient temperature was measured in four points, approximately 2 m distant from the transformer, in one half of its height. Mean value was used to process results.

The test was divided into two parts. The first one was designated for measurement of the oil temperature rise above ambient. The second one was designated for measurement of the winding temperature rise above oil.

In the first part the transformer was loaded by a current (slightly higher than the nominal one) which generated the total losses (no-load losses plus short-circuit losses) 8 631,1 W in the transformer. The losses were measured on the HV terminals side. The losses were kept constant during the test, while the current slightly changed. When oil temperature became steady, the temperature of the middle oil layer was determined.

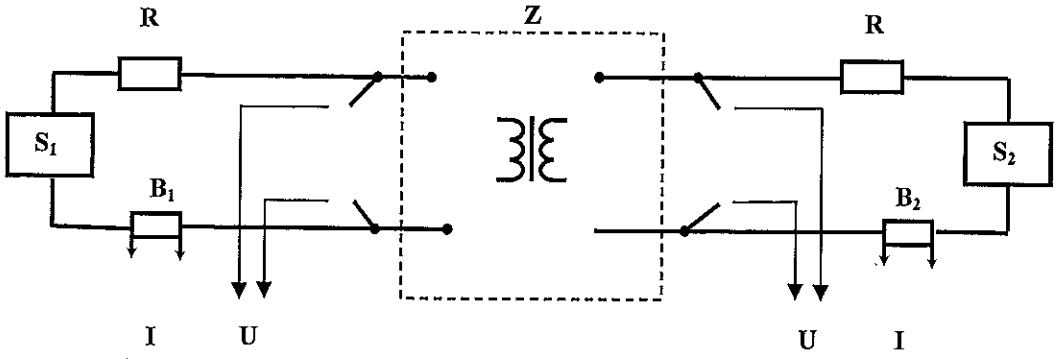
In the second part of the test the transformer was loaded by its nominal current **I** = 23.09 A for 1 hour. At the end the mean temperature of the winding and the temperature of the middle oil layer were determined.

Fig. 1: Measuring stand.



G	Generator 800 kVA,	**V**	generator breaker,
P	auxiliary transformer,	**B**	shunt for current measurement,
Z	tested transformer.		

Fig. 2: Testing power circuit for the temperature rise test.



Z	Tested transformer,	**S_1, S_2**	stabilized source of DC,
B_1, B_2	shunts for current measurement,	**R**	stabilizing resistors.

Fig. 5: Circuit for resistance measurement, arrows shows the connection to the measuring system.

Results

The test lasted 11,2 hours and it was finished according to Standard ČSN EN 60076-2 ed.2, Clause 7. Examples of time development of temperature are shown in **fig. 3**. Example of time development of interlaced and extrapolated resistance of the winding, connected to the LV and HV terminals, after the temperature rise test, are shown in **fig. 4**. Measured values of the resistance of the winding were extrapolated to the end of the temperature rise test. Recalculation between the resistances of the winding to the temperature was made by formula:

$$\Theta_2 = R_2 / R_1 \cdot (235 + \Theta_1) - 235$$

Θ_2 – temperature at the end of the test; Θ_1 – temperature before the test; R_2 – resistance of the winding at the end of the test; R_1 – resistance of the winding before the test.

Final results of temperature rise test are presented in **tab. 5.**

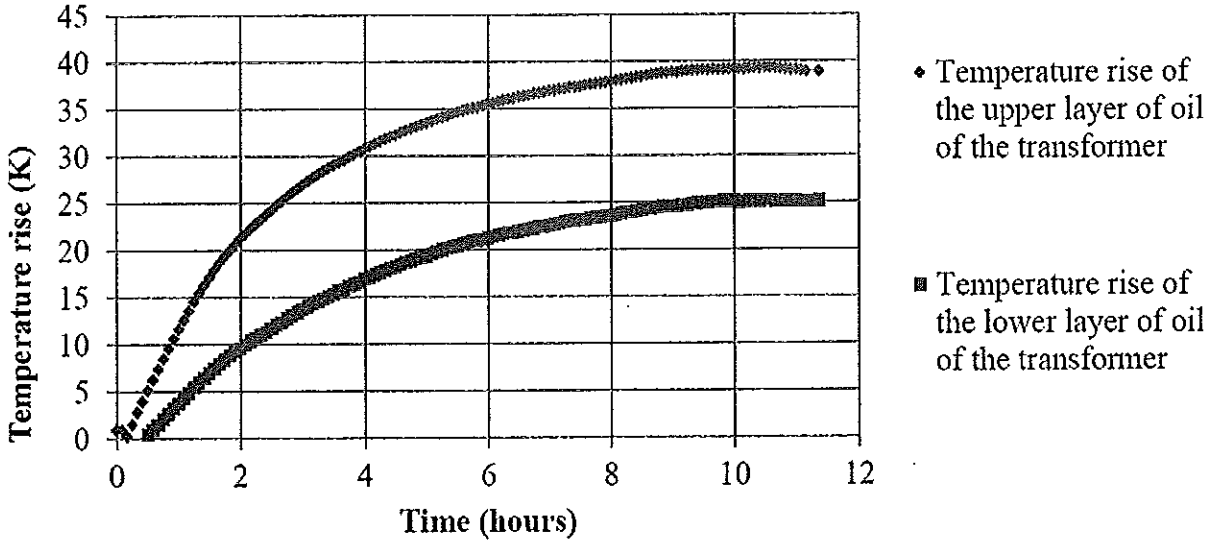


Fig. 3: Examples of temperature during the test.

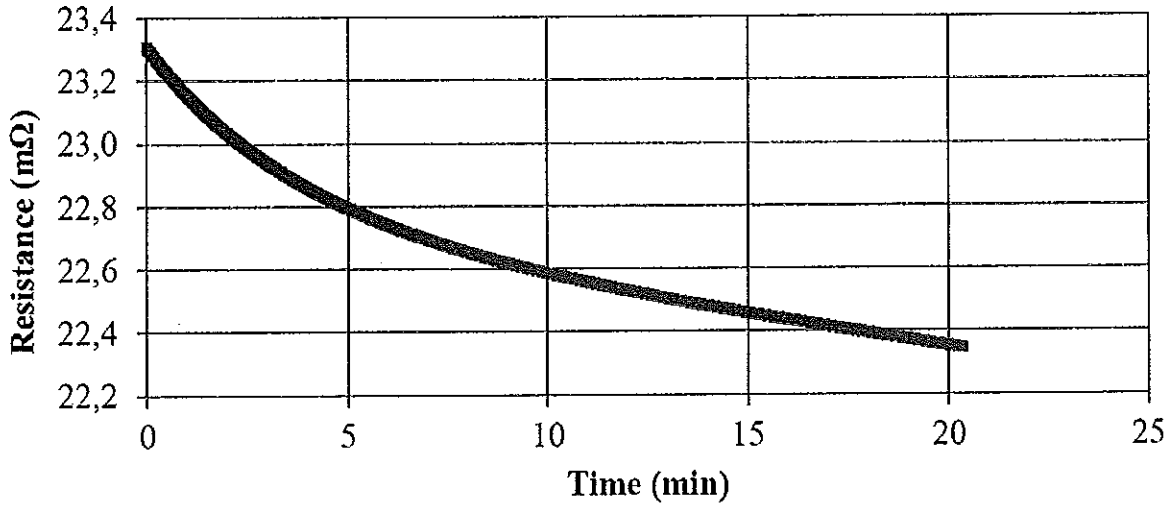


Fig. 4: Time development of interlaced and extrapolated resistances of the windings on the side of LV terminals after the temperature rise test.

		Temperature rise (K)	Limit (K)	Interpretation of test results
Temperature rise of the upper layer of oil		39.2	60	**Passed**
Middle temperature rise of the oil		32.1	--	--
Middle temperature rise of the winding	HV side	62.7	65	**Passed**
	LV side	48.3	65	**Passed**

Tab. 5: Temperature rise above ambient temperature, calculated by Standard ČSN EN 60076-2 ed.2. Uncertainty of temperature rise is maximally 1.2 K for oil measuring and 3.0 K for temperature rise test of winding. This uncertainty is calculated as product of standard uncertainty and coefficient "k", which corresponds to the interval of reliability circa 95%, which in case of standard distribution corresponds to coefficient k = 2.

Interpretation of the test results:

It is possible to certify according to the Standard ČSN EN 60076-2 ed.2, Clause. 7.11 „Uncertainties affecting the results of the temperature rise test", that the estimation of uncertainties should not be used for certification of specified limits gaining. Uncertainties should be used for information only.

Full wave lightning impulse test (LI)

Description

Full wave lightning impulse test was performed according to the Standard ČSN EN 60076-3 ed.2, Clause 13.2 at the principal tapping of the tested transformer with ratio 20/0.4 kV. The test was performed with standardized 1.2 μs $^{\pm 30\,\%}$/50 μs $^{\pm 20\,\%}$ lightning impulse of a negative polarity, **U** = 150 kV. The value of the testing voltage was chosen by the customer from the Standard ČSN EN 60076-3 ed.2, Table 2.

The test was performed for the following combination:

- 1 reference impulse (50 – 70% **U**),
- 3 impulses of 100 % **U** level.

This impulse combination was applied gradually to every phase terminal of the tested HV winding. The remaining phase terminals and the tank of the transformer were grounded. One additional measuring channel was used for the measurement of the current flowing from the remaining two interconnected phase terminal to the ground.

The lighting impulse test was performed under the following atmospheric conditions:

- atmospheric pressure: 100.2 kPa,
- temperature: 18.9 °C.

Results

The following test division and classification of each oscillogram is related to numeration, indicated under each following oscillogram **No. 1 – 13** in **figs 5-8:.**

Shape of wave – oscillogram 1.
Reference impulse – oscillograms 2 (phase 1U), 6 (phase 1V) and 10 (phase 1W).
Phase 1U – oscillograms 3, 4 and 5.
Phase 1V – oscillograms 7, 8 and 9.
Phase 1W – oscillograms 11, 12 and 13.

Interpretation of the test results:

It is evident (oscillograms in **fig. 5 - 8**) that the insulation of the tested transformer passed the lightning impulse tests (LI).

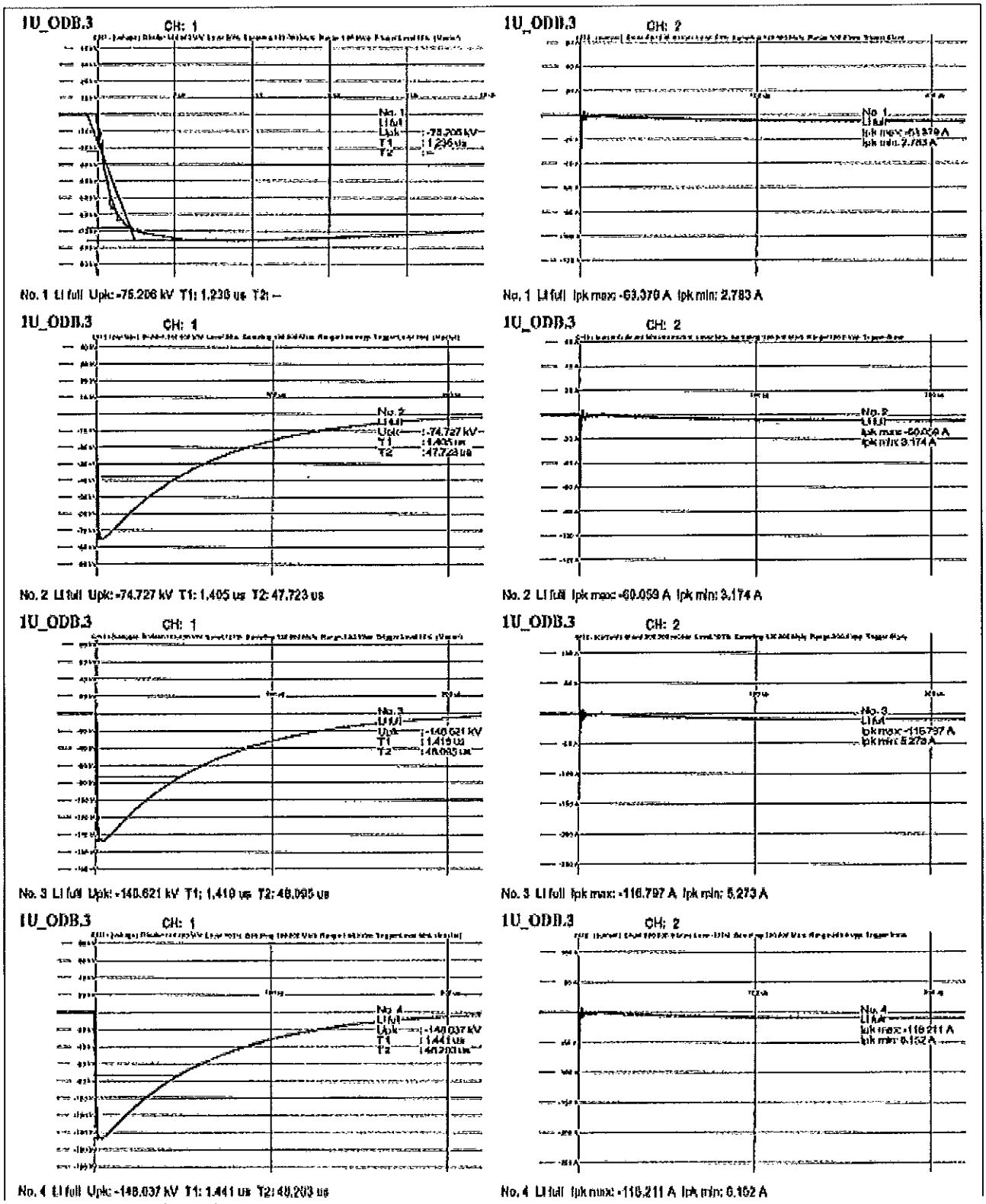


Fig. 5: Lighting impulse test.

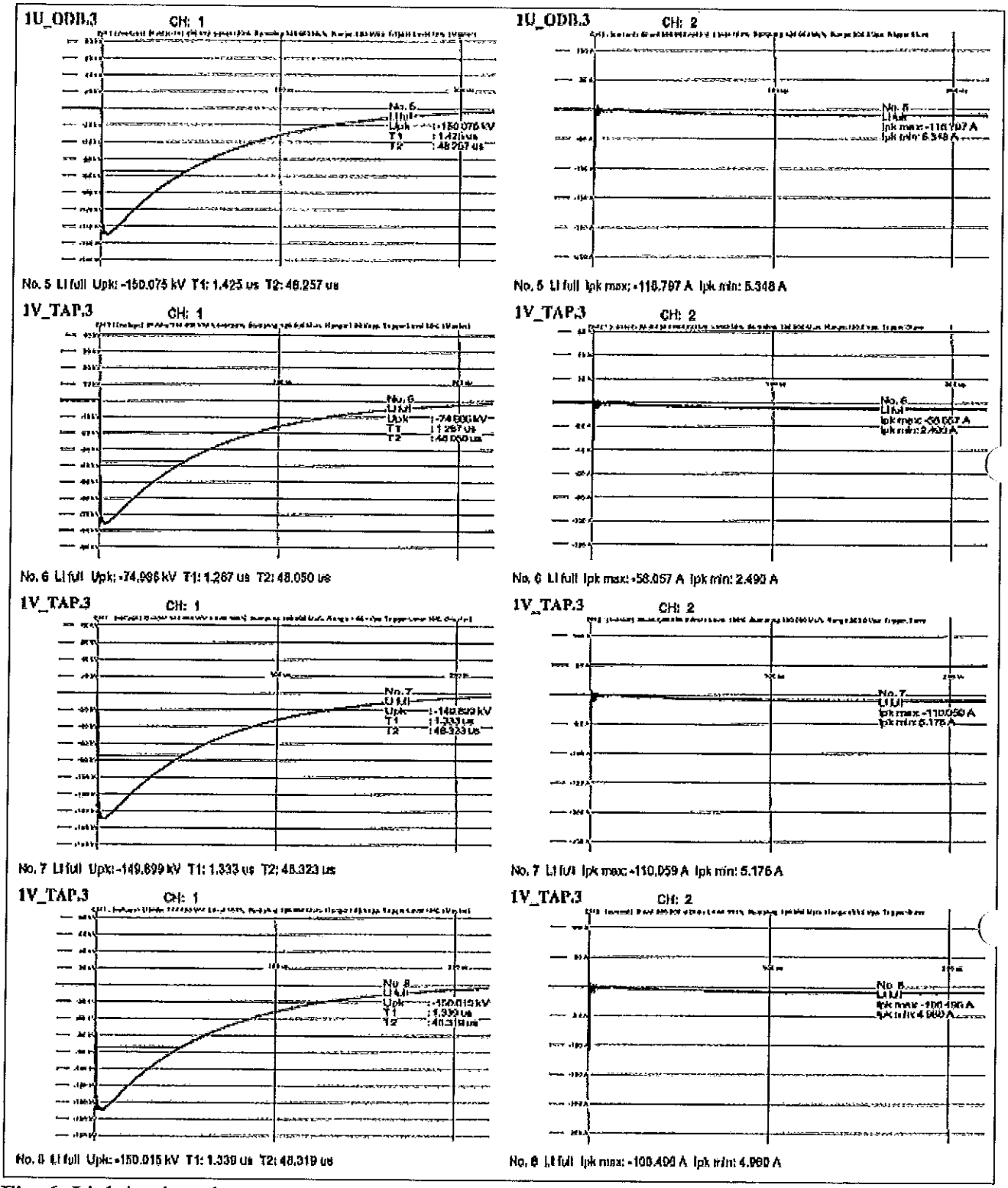


Fig. 6: Lighting impulse test.

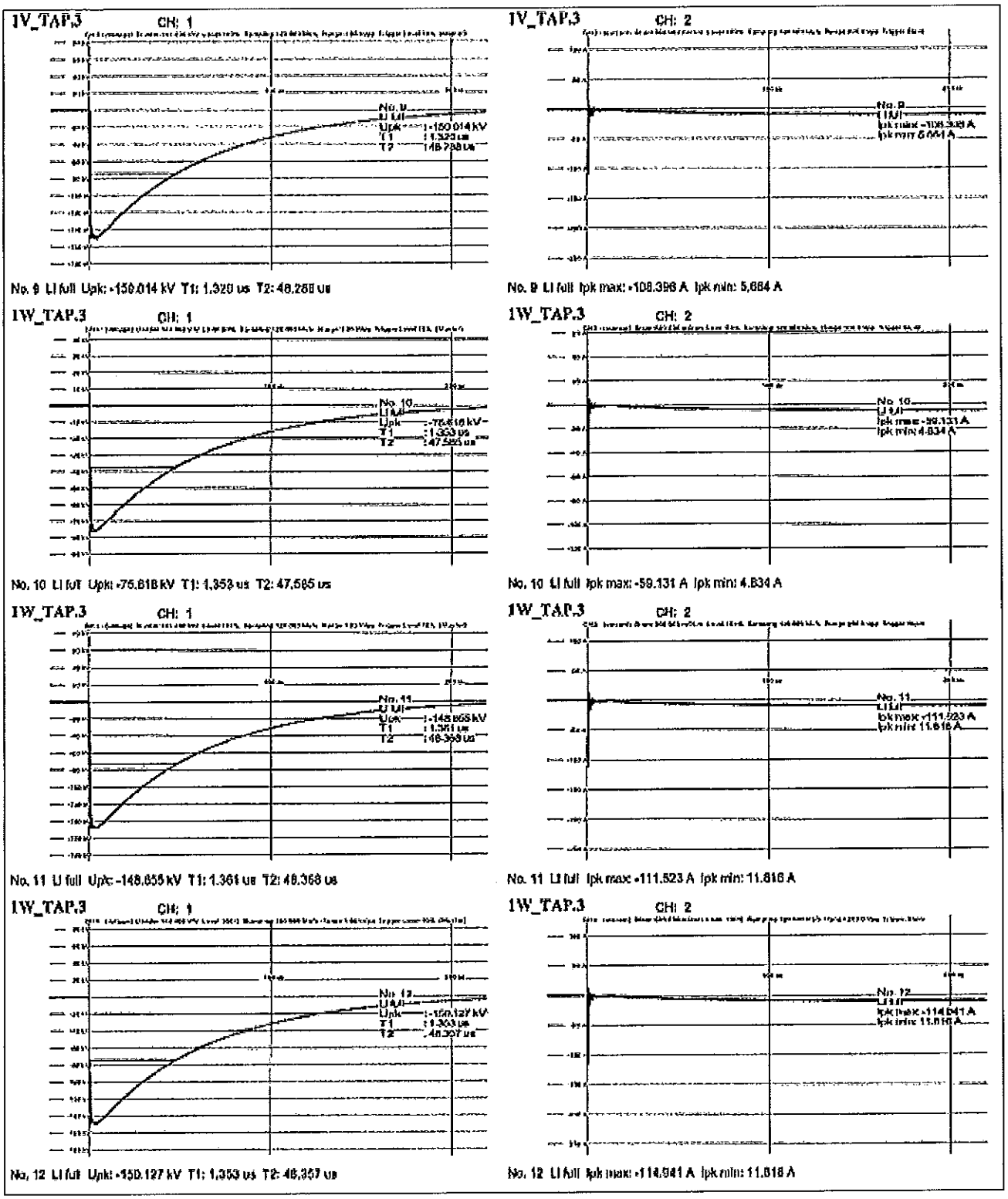


Fig. 7: Lighting impulse test.

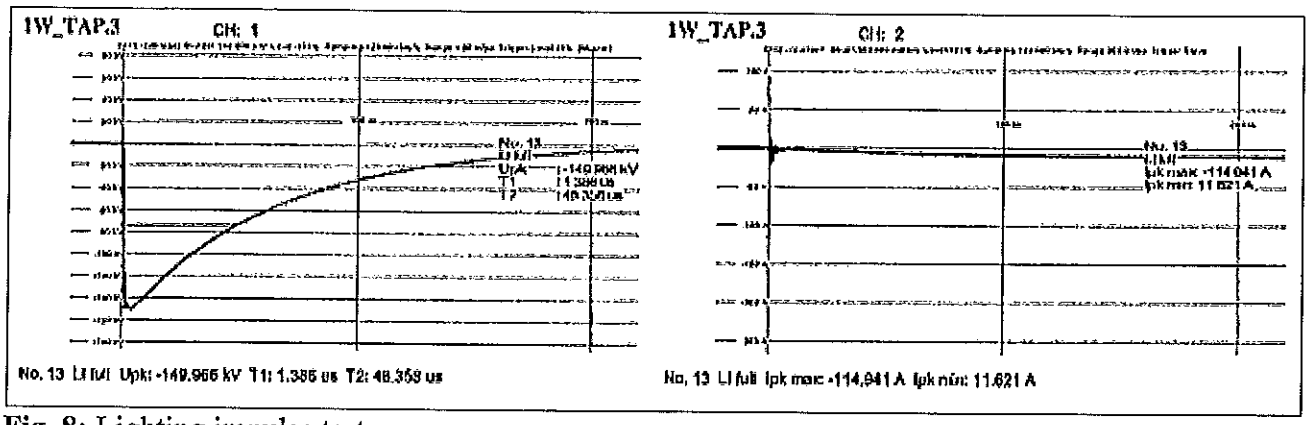


Fig. 8: Lighting impulse test.

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issues

according to section 16 of Act No. 22/1997 Coll., on technical requirements for products, as amended

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No. 660 / 2015

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Prague: 21 September 2015

Jiří Růžička
Director
Czech Accreditation Institute
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L 1526

Total sheets: 3

Test Report

AP_EZ/2016/057/01/EN

Customer:	BEZ TRANSFORMÁTORY a.s. Rybničná 40 835 54 Bratislava		
Tested object:	**Transformer tank TOHn 388/22, d.n. 608 414/9**		
Test take over date:	December 2nd , 2016		
Test realization date:	December 6th , 2016		
Test identification No.:	365-302-1628	**Evidentiary No:**	56/2016
Order No:	B06/4500006731		

Testing methods, regulations:

TESTS ACCORDING TO

ČSN EN 50464-4 Requirements and tests concerning pressurized corrugated tanks

Test results: In the text.

Enclosures: --

In Plzeň, 7th December 2016

Petr Šíma
Electrical Testing Laboratory Director

Test Report is issued in 3 copies – 2 are obtained by the customer and 1 is kept in the Laboratory.
Test Report is issued for the customer in electronic form too.

Contents

Tested object 1
Performed tests 1
Used apparatuses 1
Tank endurance test 1
Description 1
Tank static leakage test 3
Description 3
Results 3

Tested object

Corrugated tank for hermetically sealed oil-immersed transformer TOHn 388/22, drawing no. 608 414/9. The tests were performed in factory BEZ TRANSFORMATORY a.s., supervised by representative of ETD testing laboratory.

Performed tests

Special tests:

- Tank cyclic endurance test according to the Standard ČSN EN 50464-4, Clause 4.3
- Tank static leakage test according to the Standard ČSN EN 50464-4, Clause 4.4

Used apparatuses

Name	Type / Filing No.
Stopwatch	0280002584
Monitoring system	Comet MS5 + PT1000 + manometer
Testing system	Cyclic testing machine

Tank cyclic endurance test

Description

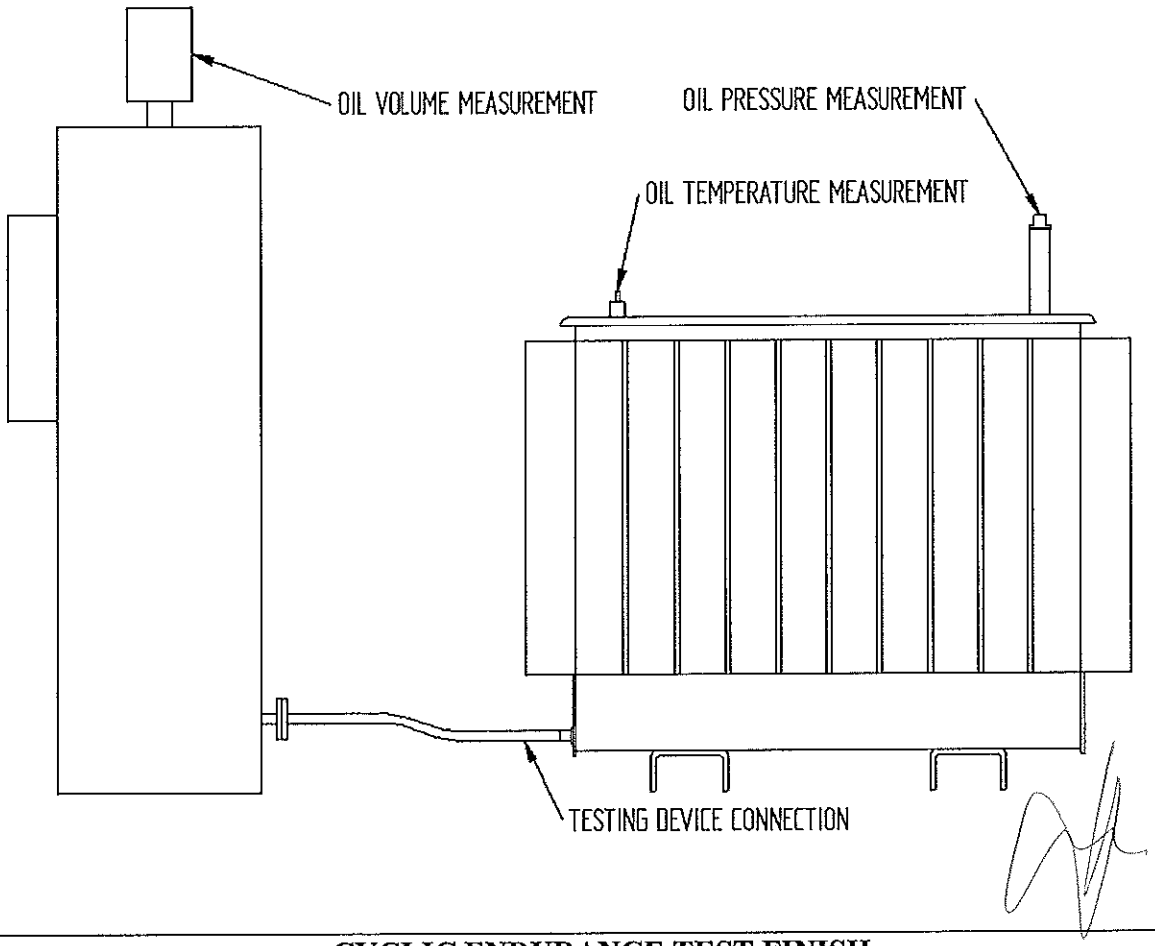
RATING VALUES OF TRANSFORMER TANK AND INITIAL PARAMETERS FOR THE TEST START		
Transformer tank drawing no.		608 414/9
Oil weight		350 kg
Initial oil volume in tank	V_0	389 dm^3
Initial tank oil temperature	T_0	20,1 °C
Volume expansion coefficient	α	0,00075 K^{-1} [mineral oil]
Oil volume added to tank	$\Delta V^+ = V_0\alpha(88-T_0)$	19,8 dm^3
Oil volume extracted from tank	$\Delta V^+ = V_0\alpha(T_0+25)$	13,2 dm^3
Max. allowed added oil volume after endurance test	[3%]	11,7 dm^3

The above calculated volume of oil (calculated according to the Standard ČSN EN 50464-4, Clause 3.3) was added or extracted from the transformer tank and the corresponding overpressure (p^+) or underpressure (p^-) was measured on the tank cover.

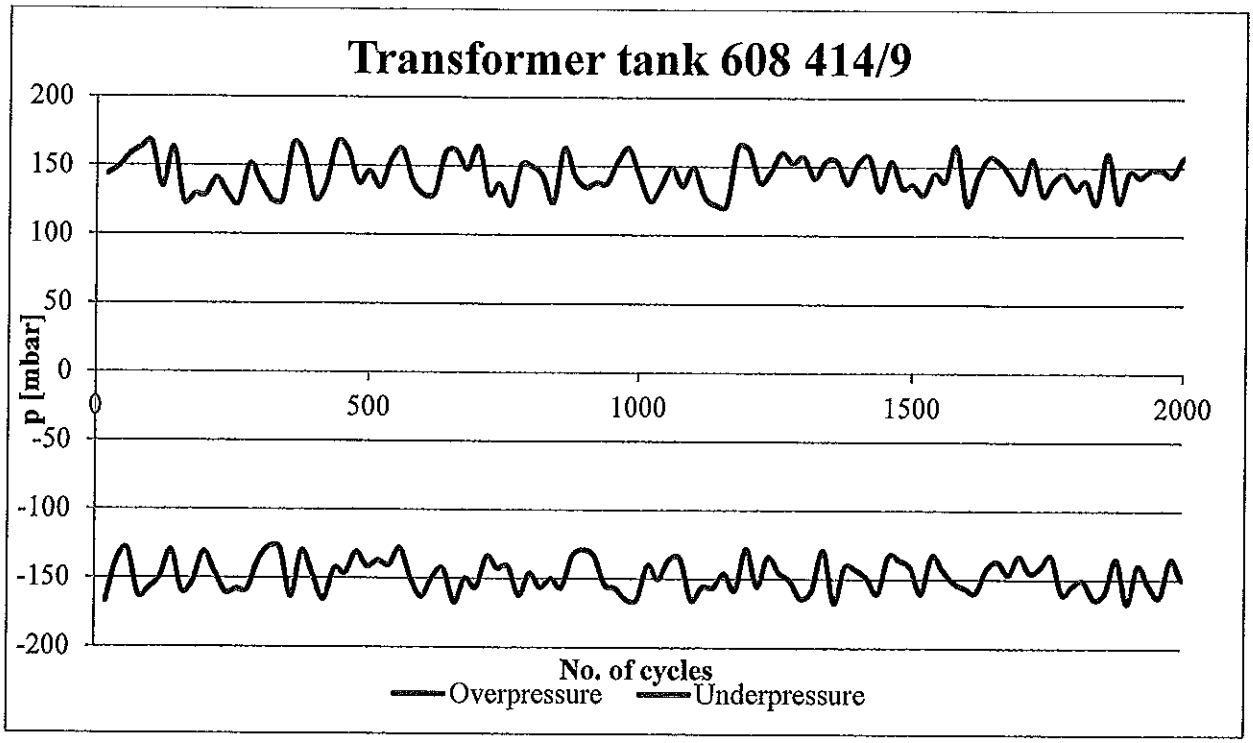
The oil temperature during the testing was the same as the initial tank oil temperature (±3°C according to the Standard ČSN EN 50464-4, Clause 4.2).

CYCLIC ENDURANCE TEST START		
Date / Time		02.12.2016 13:09
Initial Pressure in relaxed tank state	p_0	1012 mbar
Initial oil height in the testing machine	h_0	560 mm
Initial oil volume in the testing machine	V_u	29,8 dm^3
1 cycle duration		123 s

The tank endurance test was performed according to the Standard ČSN EN 50464-4, Clause 4.3. 2000 cycles of overpressure and underpressure were performed. Each cycle lasted at least 120 s. After the testing, measured oil volume was added to the tank to reach the initial pressure measured in relaxed tank state (pz = p0).



CYCLIC ENDURANCE TEST FINISH		
Date / Time		05.12.2016 12:28
No. of cycles		2000
Oil temperature at the end of the test	T_z	19,7 °C
Oil volume in testing machine after the test	V_z	23,2 dm^3
Oil volume added to the tank	$V_u - V_z$	6,6 dm^3
Pressure in relaxed tank state at the end of the test	p_z	1012 mbar
Max. pressure during the test	p_{max}	1179 mbar



Tank static leakage test

Description

The tank static leakage test was performed according to the Standard ČSN EN 50464-4, Clause 4.4. After the endurance test the tank was for 24 hours loaded with pressure, which is equal to 120% of maximum measured pressure during the endurance test.

STATIC LEAKAGE TEST		
Test pressure	$p_n=1,2(p_{max}-p_0)+p_0$	1212 mbar
Date / Time	Start	05.12.2016 13:4
Date / Time	End	06.12.2016 13:5
Test pressure	Start	1220 mbar
Test temperature	Start	19,8 °C
Test pressure	End	1218 mbar
Test temperature	End	19,4 °C

Results

After the tank endurance and the static leakage test, distribution transformer was visually inspected and **no leakage or excessive deformation was discovered.**

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L 1526

Total sheets: 3

Test Report

AP_EZ/2016/054/01/EN

Customer:	BEZ TRANSFORMÁTORY a.s. Rybničná 40 835 54 Bratislava		
Tested object:	**Transformer tank TOHn 318/22, d.n. 608 426/2**		
Test take over date:	November 22nd , 2016		
Test realization date:	November 26th , 2016		
Test identification No.:	365-302-1628	**Evidentiary No:**	56/2016
Order No:	B06/4500006731		

Testing methods, regulations:

TESTS ACCORDING TO

ČSN EN 50464-4 Requirements and tests concerning pressurized corrugated tanks

Test results: In the text.

Enclosures: --

In Plzeň, 28th November 2016

Petr Šíma
Electrical Testing Laboratory Director

Test Report is issued in 3 copies – 2 are obtained by the customer and 1 is kept in the Laboratory.
Test Report is issued for the customer in electronic form too.

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Tested object

Corrugated tank for hermetically sealed oil-immersed transformer TOHn 318/22, drawing no. 608 426/2. The tests were performed in factory BEZ TRANSFORMATORY a.s., supervised by representative of ETD testing laboratory.

Performed tests

Special tests:

- Tank cyclic endurance test according to the Standard ČSN EN 50464-4, Clause 4.3
- Tank static leakage test according to the Standard ČSN EN 50464-4, Clause 4.4

Used apparatuses

Name	Type / Filing No.
Stopwatch	0280002584
Monitoring system	Comet MS5 + PT1000 + manometer
Testing system	Cyclic testing machine

Tank cyclic endurance test

Description

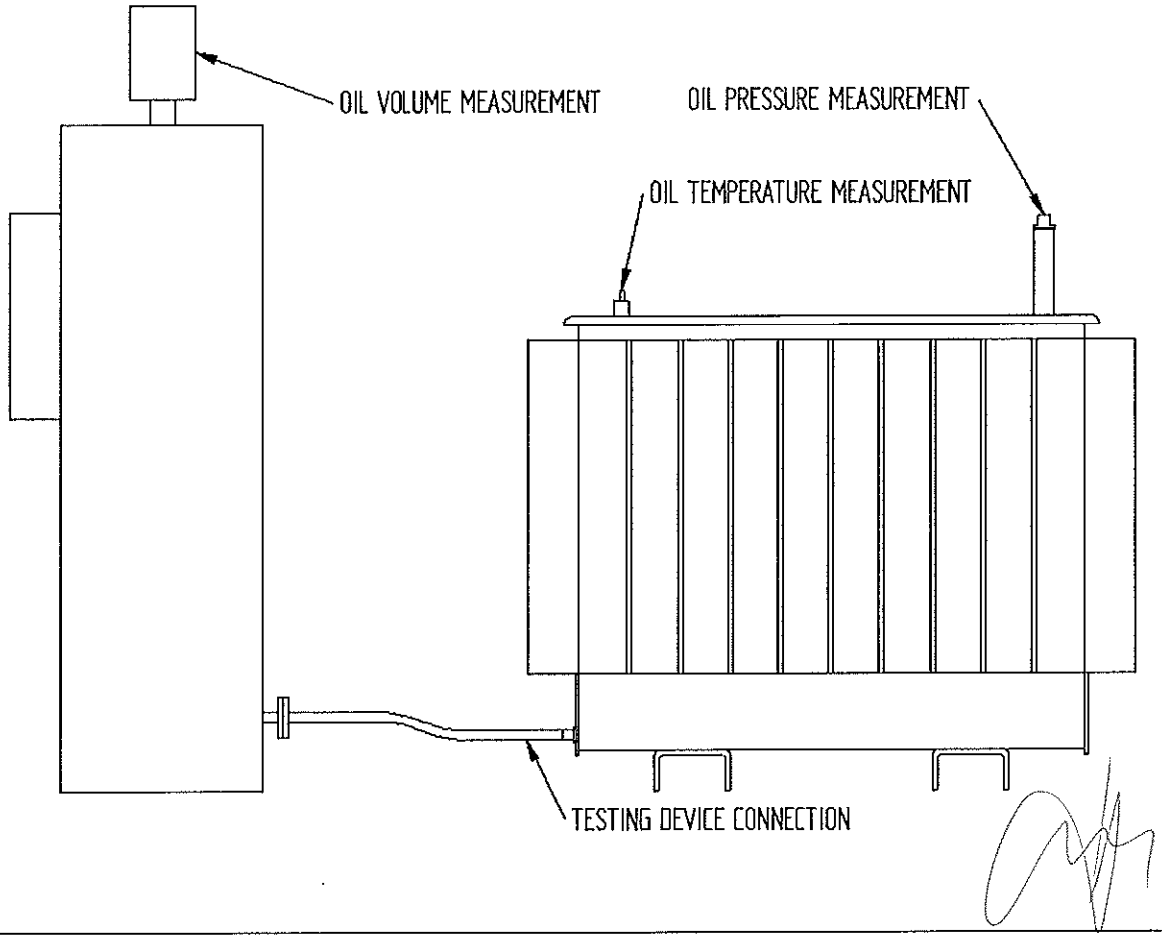
RATING VALUES OF TRANSFORMER TANK AND INITIAL PARAMETERS FOR THE TEST START		
Transformer tank drawing no.		608 426/2
Oil weight		150 kg
Initial oil volume in tank	V_0	167 dm^3
Initial tank oil temperature	T_0	19,7 °C
Volume expansion coefficient	α	0,00075 K^{-1} [mineral oil]
Oil volume added to tank	$\Delta V^+ = V_0\alpha(88-T_0)$	8,6 dm^3
Oil volume extracted from tank	$\Delta V^+ = V_0\alpha(T_0+25)$	5,6 dm^3
Max. allowed added oil volume after endurance test	[3%]	5 dm^3

The above calculated volume of oil (calculated according to the Standard ČSN EN 50464-4, Clause 3.3) was added or extracted from the transformer tank and the corresponding overpressure (p^+) or underpressure (p^-) was measured on the tank cover.

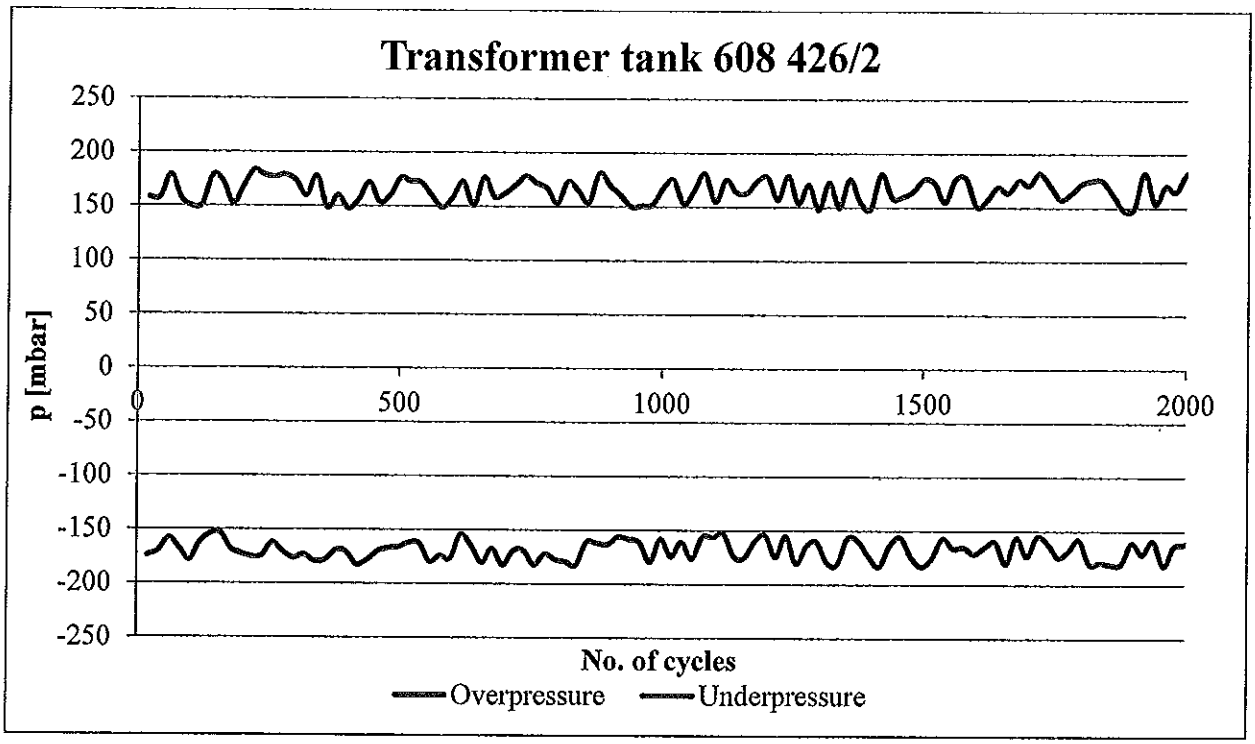
The oil temperature during the testing was the same as the initial tank oil temperature (±3°C according to the Standard ČSN EN 50464-4, Clause 4.2).

CYCLIC ENDURANCE TEST START		
Date / Time		22.11.2016 09:58
Initial Pressure in relaxed tank state	p_0	1013 mbar
Initial oil height in the testing machine	h_0	350 mm
Initial oil volume in the testing machine	V_u	18,6 dm^3
1 cycle duration		123 s

The tank endurance test was performed according to the Standard ČSN EN 50464-4, Clause 4.3. 2000 cycles of overpressure and underpressure were performed. Each cycle lasted at least 120 s. After the testing, measured oil volume was added to the tank to reach the initial pressure measured in relaxed tank state (pz = p0).



CYCLIC ENDURANCE TEST FINISH		
Date / Time		25.11.2016 09:36
No. of cycles		2000
Oil temperature at the end of the test	T_z	19,2 °C
Oil volume in testing machine after the test	V_z	15,4 dm^3
Oil volume added to the tank	$V_u - V_z$	3,2 dm^3
Pressure in relaxed tank state at the end of the test	p_z	1013 mbar
Max. pressure during the test	p_{max}	1196 mbar



Tank static leakage test

Description

The tank static leakage test was performed according to the Standard ČSN EN 50464-4, Clause 4.4. After the endurance test the tank was for 24 hours loaded with pressure, which is equal to 120% of maximum measured pressure during the endurance test.

STATIC LEAKAGE TEST		
Test pressure	$p_n=1,2(p_{max}-p_0)+p_0$	1233 mbar
Date / Time	Start	25.11.2016 10:23
Date / Time	End	26.11.2016 10:3
Test pressure	Start	1236 mbar
Test temperature	Start	19,6 °C
Test pressure	End	1234 mbar
Test temperature	End	19,7 °C

Results

After the tank endurance and the static leakage test, distribution transformer was visually inspected and **no leakage or excessive deformation was discovered.**

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L 1526

Total sheets: 3

Test Report

AP_EZ/2016/055/01/EN

Customer:	BEZ TRANSFORMÁTORY a.s. Rybničná 40 835 54 Bratislava		
Tested object:	**Transformer tank TOHn 358/22, d.n. 609 971/2**		
Test take over date:	November 25th , 2016		
Test realization date:	November 29th , 2016		
Test identification No.:	365-302-1628	**Evidentiary No:**	56/2016
Order No:	B06/4500006731		

Testing methods, regulations:

TESTS ACCORDING TO

ČSN EN 50464-4 Requirements and tests concerning pressurized corrugated tanks

Test results: In the text.

Enclosures: --

In Plzeň, 01st December 2016

Petr Šíma
Electrical Testing Laboratory Director

Test Report is issued in 3 copies – 2 are obtained by the customer and 1 is kept in the Laboratory.
Test Report is issued for the customer in electronic form too.

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Tested object

Corrugated tank for hermetically sealed oil-immersed transformer TOHn 358/22, drawing no. 609 971/2. The tests were performed in factory BEZ TRANSFORMATORY a.s., supervised by representative of ETD testing laboratory.

Performed tests

Special tests:

- Tank cyclic endurance test according to the Standard ČSN EN 50464-4, Clause 4.3
- Tank static leakage test according to the Standard ČSN EN 50464-4, Clause 4.4

Used apparatuses

Name	Type / Filing No.
Stopwatch	0280002584
Monitoring system	Comet MS5 + PT1000 + manometer
Testing system	Cyclic testing machine

Tank cyclic endurance test

Description

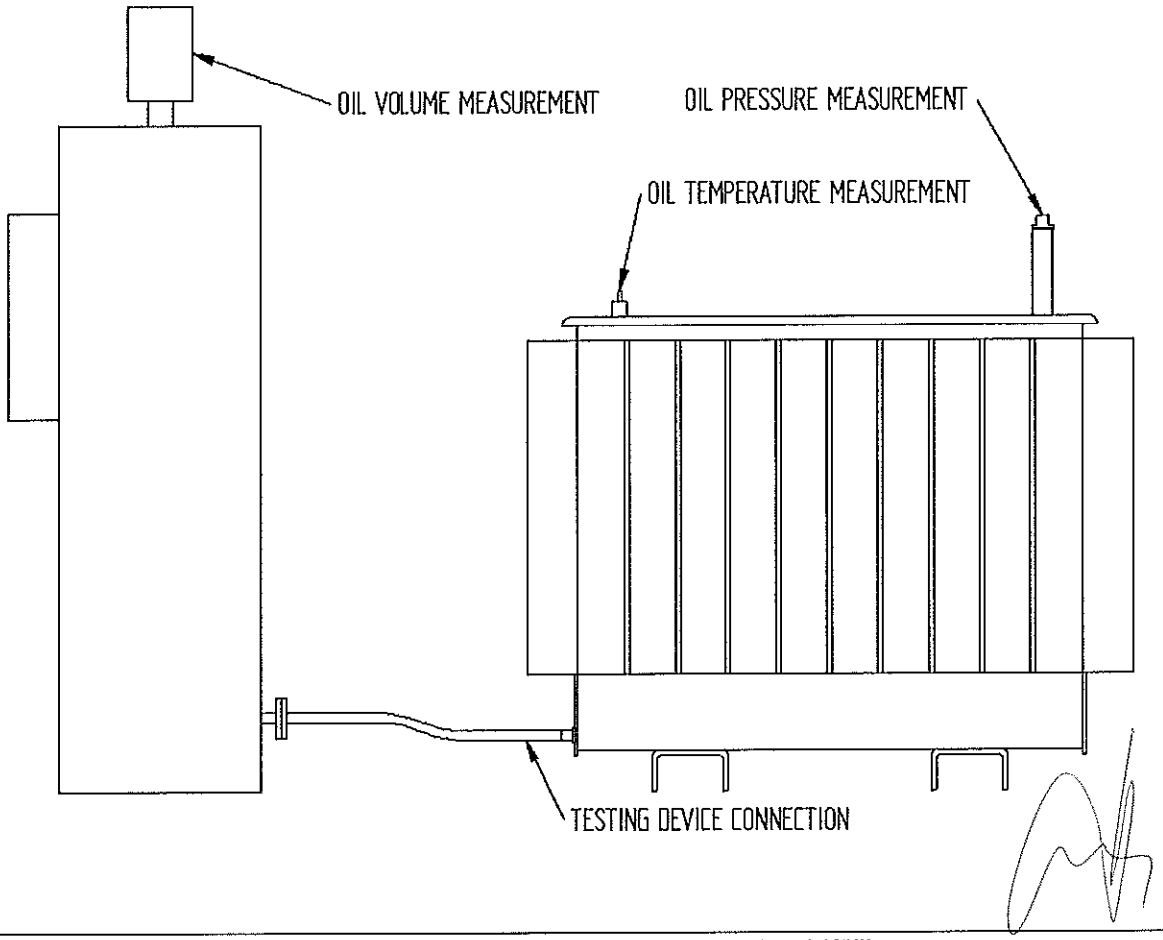
RATING VALUES OF TRANSFORMER TANK AND INITIAL PARAMETERS FOR THE TEST START		
Transformer tank drawing no.		609 971/2
Oil weight		200 kg
Initial oil volume in tank	V_0	223 dm^3
Initial tank oil temperature	T_0	19,2 °C
Volume expansion coefficient	α	0,00075 K^{-1} [mineral oil]
Oil volume added to tank	$\Delta V^+ = V_0\alpha(88-T_0)$	11,5 dm^3
Oil volume extracted from tank	$\Delta V^+ = V_0\alpha(T_0+25)$	7,4 dm^3
Max. allowed added oil volume after endurance test	[3%]	6,7 dm^3

The above calculated volume of oil (calculated according to the Standard ČSN EN 50464-4, Clause 3.3) was added or extracted from the transformer tank and the corresponding overpressure (p^+) or underpressure (p^-) was measured on the tank cover.

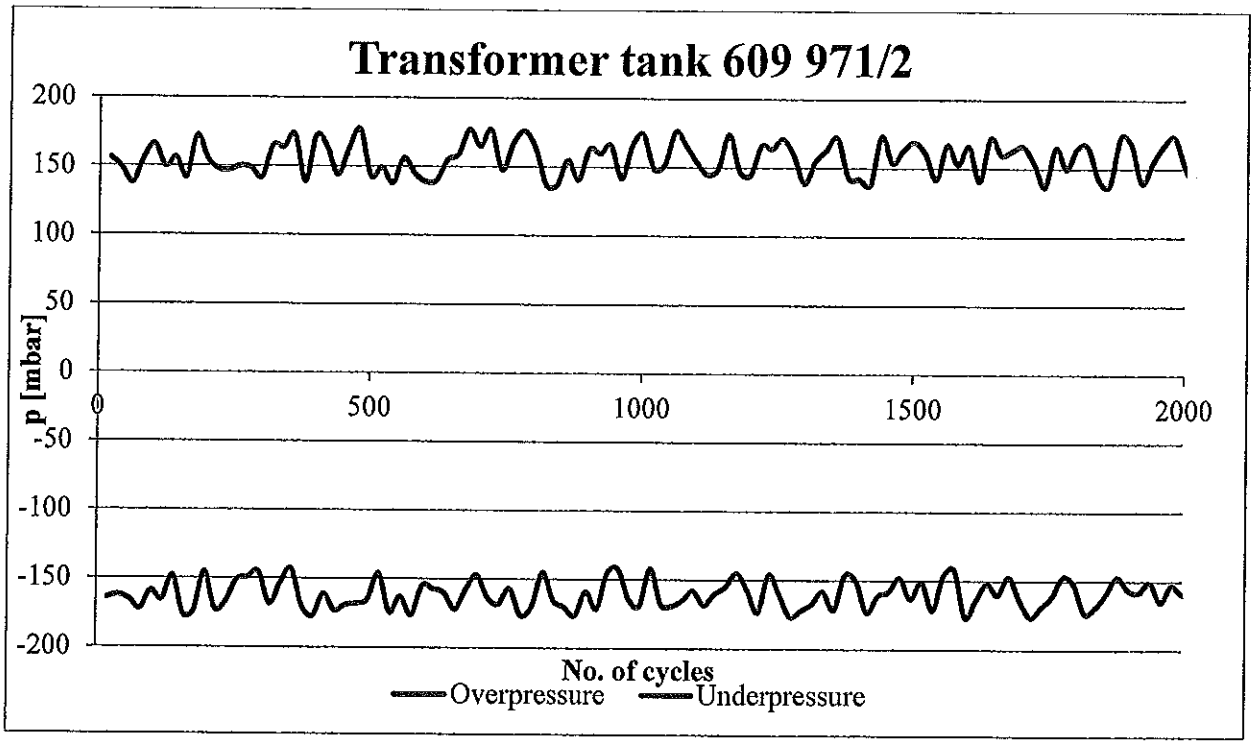
The oil temperature during the testing was the same as the initial tank oil temperature (±3°C according to the Standard ČSN EN 50464-4, Clause 4.2).

CYCLIC ENDURANCE TEST START		
Date / Time		25.11.2016 12:52
Initial Pressure in relaxed tank state	p_0	1012 mbar
Initial oil height in the testing machine	h_0	404 mm
Initial oil volume in the testing machine	V_u	21,5 dm^3
1 cycle duration		124 s

The tank endurance test was performed according to the Standard ČSN EN 50464-4, Clause 4.3. 2000 cycles of overpressure and underpressure were performed. Each cycle lasted at least 120 s. After the testing, measured oil volume was added to the tank to reach the initial pressure measured in relaxed tank state (pz = p0).



CYCLIC ENDURANCE TEST FINISH		
Date / Time		28.11.2016 12:34
No. of cycles		2000
Oil temperature at the end of the test	T_z	19,6 °C
Oil volume in testing machine after the test	V_z	17,5 dm^3
Oil volume added to the tank	$V_u - V_z$	4 dm^3
Pressure in relaxed tank state at the end of the test	p_z	1012 mbar
Max. pressure during the test	p_{max}	1189 mbar



Tank static leakage test

Description

The tank static leakage test was performed according to the Standard ČSN EN 50464-4, Clause 4.4. After the endurance test the tank was for 24 hours loaded with pressure, which is equal to 120% of maximum measured pressure during the endurance test.

STATIC LEAKAGE TEST		
Test pressure	$p_n=1,2(p_{max}-p_0)+p_0$	1224 mbar
Date / Time	Start	28.11.2016 13:1[illegible]
Date / Time	End	29.11.2016 13:2[illegible]
Test pressure	Start	1237 mbar
Test temperature	Start	19,8 °C
Test pressure	End	1234 mbar
Test temperature	End	19,6 °C

Results

After the tank endurance and the static leakage test, distribution transformer was visually inspected and **no leakage or excessive deformation was discovered.**

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Total sheets: 3

Test Report

AP_EZ/2016/056/01/EN

Customer:	BEZ TRANSFORMÁTORY a.s. Rybničná 40 835 54 Bratislava		
Tested object:	**Transformer tank TOHn 378/22, d.n. 610 022/4**		
Test take over date:	November 29th , 2016		
Test realization date:	December 3rd , 2016		
Test identification No.:	365-302-1628	**Evidentiary No:**	56/2016
Order No:	B06/4500006731		

Testing methods, regulations:

TESTS ACCORDING TO

ČSN EN 50464-4 Requirements and tests concerning pressurized corrugated tanks

Test results: In the text.

Enclosures: --

In Plzeň, 5th December 2016

Petr Šíma
Electrical Testing Laboratory Director

Test Report is issued in 3 copies – 2 are obtained by the customer and 1 is kept in the Laboratory.
Test Report is issued for the customer in electronic form too.

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Tested object

Corrugated tank for hermetically sealed oil-immersed transformer TOHn 378/22, drawing no. 610 022/4. The tests were performed in factory BEZ TRANSFORMATORY a.s., supervised by representative of ETD testing laboratory.

Performed tests

Special tests:

- Tank cyclic endurance test according to the Standard ČSN EN 50464-4, Clause 4.3
- Tank static leakage test according to the Standard ČSN EN 50464-4, Clause 4.4

Used apparatuses

Name	Type / Filing No.
Stopwatch	0280002584
Monitoring system	Comet MS5 + PT1000 + manometer
Testing system	Cyclic testing machine

Tank cyclic endurance test

Description

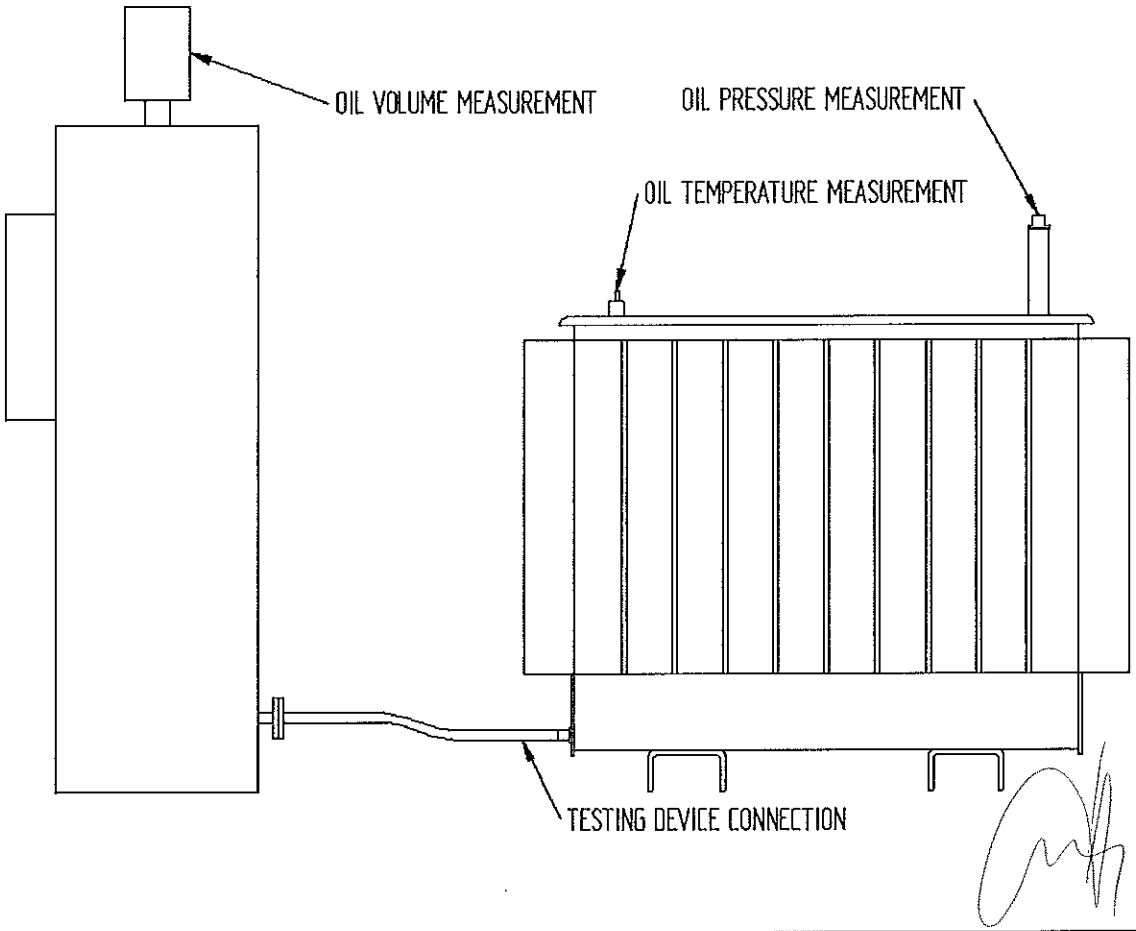
RATING VALUES OF TRANSFORMER TANK AND INITIAL PARAMETERS FOR THE TEST START		
Transformer tank drawing no.		610 022/4
Oil weight		210 kg
Initial oil volume in tank	V_0	234 dm^3
Initial tank oil temperature	T_0	19,7 °C
Volume expansion coefficient	α	0,00075 K^{-1} [mineral oil]
Oil volume added to tank	$\Delta V^+ = V_0\alpha(88-T_0)$	12 dm^3
Oil volume extracted from tank	$\Delta V^+ = V_0\alpha(T_0+25)$	7,8 dm^3
Max. allowed added oil volume after endurance test	[3%]	7 dm^3

The above calculated volume of oil (calculated according to the Standard ČSN EN 50464-4, Clause 3.3) was added or extracted from the transformer tank and the corresponding overpressure (p^+) or underpressure (p^-) was measured on the tank cover.

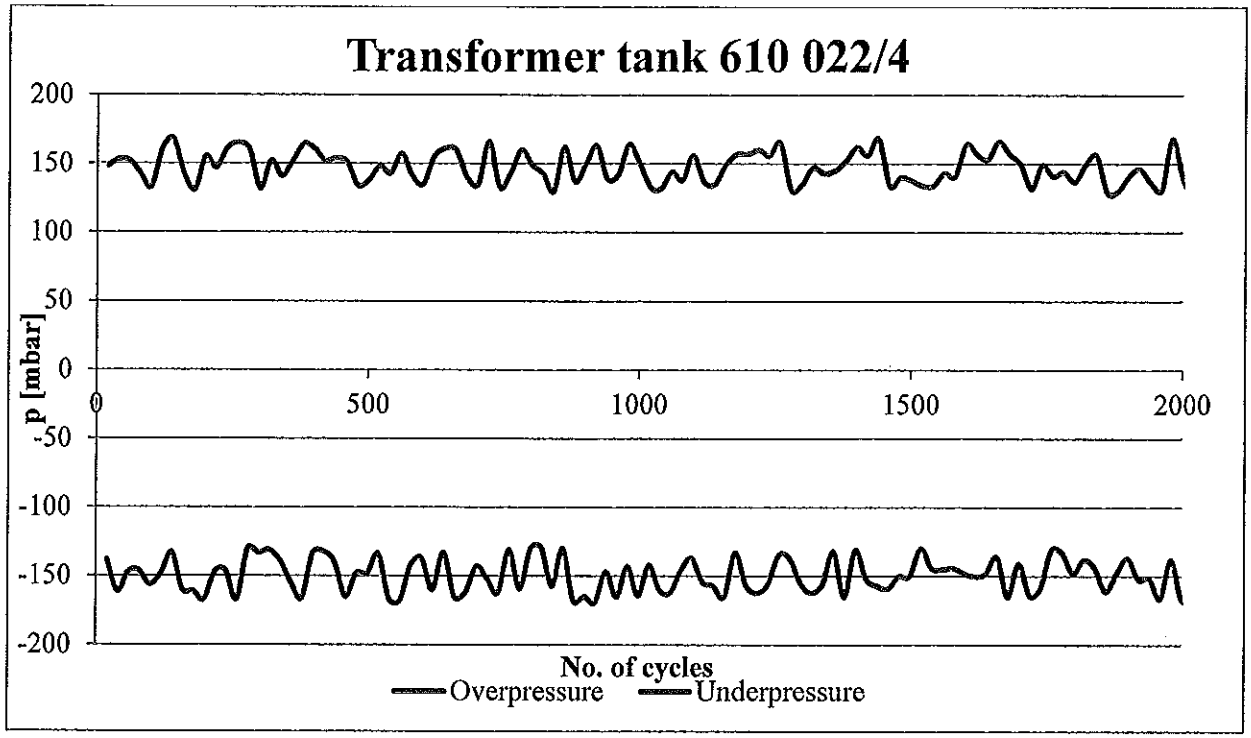
The oil temperature during the testing was the same as the initial tank oil temperature (±3°C according to the Standard ČSN EN 50464-4, Clause 4.2).

CYCLIC ENDURANCE TEST START		
Date / Time		29.11.2016 10:16
Initial Pressure in relaxed tank state	p_0	1013 mbar
Initial oil height in the testing machine	h_0	414 mm
Initial oil volume in the testing machine	V_u	22 dm^3
1 cycle duration		124 s

The tank endurance test was performed according to the Standard ČSN EN 50464-4, Clause 4.3. 2000 cycles of overpressure and underpressure were performed. Each cycle lasted at least 120 s. After the testing, measured oil volume was added to the tank to reach the initial pressure measured in relaxed tank state (pz = p0).



CYCLIC ENDURANCE TEST FINISH		
Date / Time		02.12.2016 09:28
No. of cycles		2000
Oil temperature at the end of the test	T_z	19,4 °C
Oil volume in testing machine after the test	V_z	17,8 dm^3
Oil volume added to the tank	$V_u - V_z$	4,2 dm^3
Pressure in relaxed tank state at the end of the test	p_z	1013 mbar
Max. pressure during the test	p_{max}	1182 mbar



Tank static leakage test

Description

The tank static leakage test was performed according to the Standard ČSN EN 50464-4, Clause 4.4. After the endurance test the tank was for 24 hours loaded with pressure, which is equal to 120% of maximum measured pressure during the endurance test.

STATIC LEAKAGE TEST		
Test pressure	$p_n=1,2(p_{max}-p_0)+p_0$	1216 mbar
Date / Time	Start	02.12.2016 10:4
Date / Time	End	03.12.2016 10:5
Test pressure	Start	1225 mbar
Test temperature	Start	19,6 °C
Test pressure	End	1223 mbar
Test temperature	End	19,4 °C

Results

After the tank endurance and the static leakage test, distribution transformer was visually inspected and **no leakage or excessive deformation was discovered.**

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L 1526

Total sheets: 14

Test Report

AP_EZ/2016/047/01/EN

Customer:	BEZ TRANSFORMÁTORY a.s. Rybničná 40 835 54 Bratislava		
Tested object:	**Transformer TOHn 319/22, s.n. 0361960**		
Test take over date:	September 23th , 2016		
Test realization date:	September 26th , 2016		
Test identification No.:	365-302-1624	**Evidentiary No:**	48/2016
Order No:	B06/4500006720		

Testing methods, regulations:

ACCREDITED TESTS ACCORDING TO SOP_EZ/2, 4, 6 and 8:

ČSN EN 60076-1, Clause 11.2	Measurement of winding resistance
ČSN EN 60076-1, Clause 11.4	Measurement of short-circuit impedance and load loss
ČSN EN 60076-1, Clause 11.5	Measurement of no-load loss and current
ČSN EN 60076-2 ed.2	Power transformer – Part 2: Temperature rise for liquid-immersed transformers
ČSN EN 60076-3 ed.2, Clause 13.2	Full wave lightning impulse test (LI)

Test results: In the text.

Enclosures: --

In Plzeň, 30th September 2016

Petr Šíma
Electrical Testing Laboratory Director

Test Report is issued in 3 copies – 2 are obtained by the customer and 1 is kept in the Laboratory.
Test Report is issued for the customer in electronic form too.

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Description 5
Results 6
Full wave lightning impulse test (LI) 9
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Results 9

Tested object

Oil-immersed transformer TOHn 319/22.

Performed tests

Routine tests:

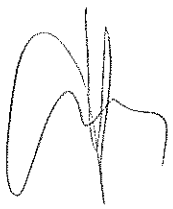
- Measurement of winding resistance according to the Standard ČSN EN 60076-1, Clause 11.2. The test was carried out at tappings 1, 3 and 5 of the tested transformer.
- Measurement of short-circuit impedance and load loss according to the Standard ČSN EN 60076-1, Clause 11.4. The test was carried out at tappings 1, 3 and 5 of the tested transformer.
- Measurement of no-load loss and current according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the switch P1 of the tested transformer.

Type tests:

- Temperature rise test according to the Standard ČSN EN 60076-2 ed.2 at tapping 3 of the tested transformer with ratio 20/0.4 kV.
- Full wave lightning impulse test (LI) of the tested transformer according to the Standard ČSN EN 60076-3 ed.2, Clause 13.2. Test was carried out at HV side with negative wave 150 kV.

Used apparatuses

Name	Type	Filing No.
Digital multimeter	Fluke 189	PMMm 263
Digital multimeter	Fluke 179	PMMm 269
Digital oscilloscope	AT DSO7034A	PMMo 265
Digital oscilloscope	Keysight DSO-X 4034A	PMMo 270
Isolating converters	BB3652	PMMp 254
Mercury thermometer	from 0°C to 50°C	PMMt 239
Digital thermometer	GMH 3710	PMMt 268
Current transformer	ABB Petercem EA100	PMTr 92
Current transformer	ABB Petercem EA100	PMTr 93
Current transformer	ABB Petercem EA100	PMTr 94
Three-phase power analyzer	D6100	PMWa 19
Power analyzer	Norma 5000	PMWa 27
Impulse Analyzing System	HiAS 743	176736



Measurement of winding resistance

Description

The measurement of winding resistance was performed according to the Standard ČSN EN 60076-1, Clause 11.2.3. Measurement was carried out at tappings 1, 3 and 5 of the tested transformer in temperature steady state.

Winding resistances each of above mentioned tappings were measured with DC current, with Ohm's method, between terminals of each phase on HV side of transformer and between node and terminal of respective phase on LV side of tested transformer. The mean temperature of cooling liquid (temperature of transformer winding) was measured during the test. Temperature was between 22.2 °C and 22.7 °C. Resulting value of the resistance was recalculated to 75 °C.

Results

Resistances of transformer winding are noted in **Tab. 1.**

Side of transformer	Tap	Terminal	Before type and special tests	
			$R_{measured}$ (Ω)	R_{75} (Ω)
HV	1 (+ 5 %)	1U – 1V	36.53001464	44.02917783
		1U – 1W	36.60274932	44.13853922
		1V – 1W	36.58698981	44.08071062
	3 (0 %)	1U – 1V	34.60412508	41.70792681
		1U – 1W	34.71354513	41.83980945
		1V – 1W	34.68085106	41.78415791
	5 (- 5 %)	1U – 1V	32.73462354	39.45463957
		1U – 1W	32.81904635	39.54101970
		1V – 1W	32.79462623	39.51159787
LV		2n – 2u	0.004330360	0.005209203
		2n – 2v	0.004199683	0.005052005
		2n – 2w	0.004212380	0.005067280

Tab. 1: Resistances of transformer winding.

Measurement of short-circuit impedance and load loss

Description

Measurement of short-circuit impedance and load loss was performed according to the Standard ČSN EN 60076-1, Clause 11.4. The test was carried out at tappings 1, 3 and 5 of the tested transformer in temperature steady state.

Voltage was applied to HV terminals of the transformer, LV terminals were short circuited. Supply current of 50 Hz was ca. 3 A. Temperature was 22.6 °C.

Measured values of short-circuit impedance and load loss were corrected for the reference temperature 75 °C.

Results

Measured values of short-circuit impedance and load loss are noted in **Tab. 2.**

	Z a Δ P_k		
Tapping	1 (+ 5 %)	3 (0 %)	5 (- 5 %)
$Z_{measured}$ (Ω)	116.40	103.77	93.66
Z_{75} (Ω)	117.86	105.42	95.52
Δ $P_{k\ measured}$ (W)	1 574.43	1 864.00	2 216.87
Δ $P_{k\ 75}$ (W)	1 914.73	2 210.48	2 574.23

Tab. 2: Values of the short-circuit impedance and load loss.

Measurement of no-load loss and currents

Description

Measurement of no-load losses and currents was performed according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the tested transformer in temperature steady state.

Supply voltage was applied to LV terminals of the transformer; HV terminals were no-loaded. Supply voltage during the measurement was set to 90 %, 100 % and 110 % of rated voltage U_2.

Results

Measured values of no-load losses and currents are noted in **tab. 3** and **4**.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
Δ P_0 (W)	160.2	203.0	264.1

Tab. 3: Values of the no-load losses.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
I_0 (A)	0.6932	0.7421	0.8351

Tab. 4: Values of the no-load currents.

Temperature rise test

Description

Short-circuit method was used. Transformer was connected to the testing circuit according to the **fig. 1**. Lead-in copper cables 16 mm^2 on the side of HV terminals and copper pas with dimension ca. 800 mm^2 on the side of LV terminals were used. Frequency of power source was **f** = 50 Hz.

Mean temperature of the side of the HV and LV winding was determined by measuring of electrical resistance of the winding. Wiring is shown in **fig. 2**. The resistance was measured by Ohm´s method on both sides. At the end of the test, the time development of the resistance was recorded from the moment after switching circuits and electrical stabilization of the measuring circuit. The development was extrapolated to the moment when testing current was switched off.

Other temperatures were measured by thermocouples in connection with a measuring system. Oil temperature was measured in the oil sump at the top of the transformer. Side surface temperature was measured in eight points, four ones up and four ones down, close to corners of the transformer container. These values were used to calculate the temperature of the middle oil layer.

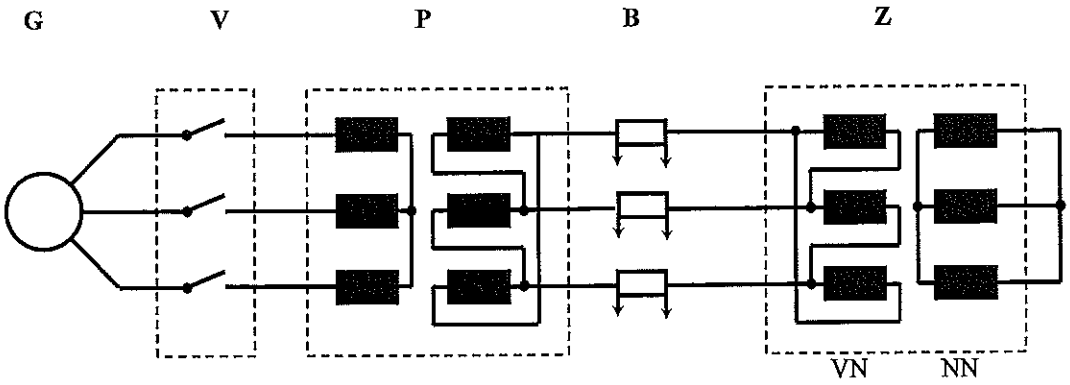
Ambient temperature was measured in four points, approximately 2 m distant from the transformer, in one half of its height. Mean value was used to process results.

The test was divided into two parts. The first one was designated for measurement of the oil temperature rise above ambient. The second one was designated for measurement of the winding temperature rise above oil.

In the first part the transformer was loaded by a current (slightly higher than the nominal one) which generated the total losses (no-load losses plus short-circuit losses) 2 414.4 W in the transformer. The losses were measured on the HV terminals side. The losses were kept constant during the test, while the current slightly changed. When oil temperature became steady, the temperature of the middle oil layer was determined.

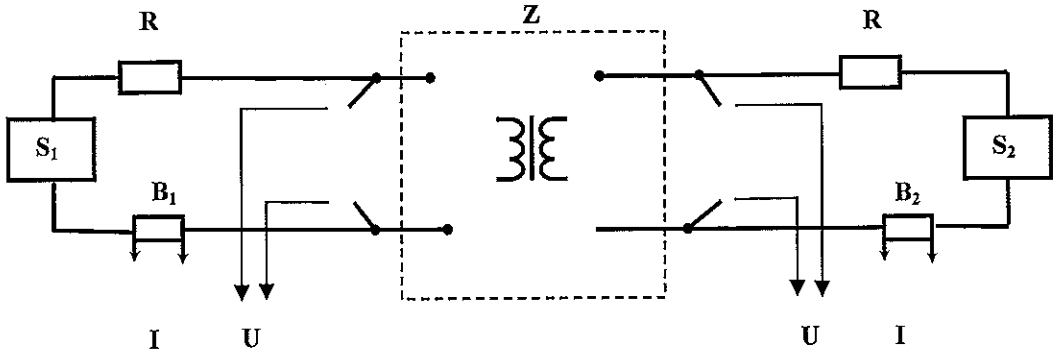
In the second part of the test the transformer was loaded by its nominal current **I** = 4.62 A for 1 hour. At the end the mean temperature of the winding and the temperature of the middle oil layer were determined.

Fig. 1: Measuring stand.



G	Generator 800 kVA,	**V**	generator breaker,
P	auxiliary transformer,	**B**	shunt for current measurement,
Z	tested transformer.		

Fig. 2: Testing power circuit for the temperature rise test.



Z	Tested transformer,	**S_1, S_2**	stabilized source of DC,
B_1, B_2	shunts for current measurement,	**R**	stabilizing resistors.

Fig. 5: Circuit for resistance measurement, arrows shows the connection to the measuring system.

Results

The test lasted 11.7 hours and it was finished according to Standard ČSN EN 60076-2 ed.2, Clause 7. Examples of time development of temperature are shown in **fig. 3**. Example of time development of interlaced and extrapolated resistance of the winding, connected to the LV and HV terminals, after the temperature rise test, are shown in **fig. 4**. Measured values of the resistance of the winding were extrapolated to the end of the temperature rise test. Recalculation between the resistances of the winding to the temperature was made by formula:

$$\Theta_2 = R_2 / R_1 \cdot (235 + \Theta_1) - 235$$

Θ_2 – temperature at the end of the test; Θ_1 – temperature before the test; R_2 – resistance of the winding at the end of the test; R_1 – resistance of the winding before the test.

Final results of temperature rise test are presented in **tab. 5.**

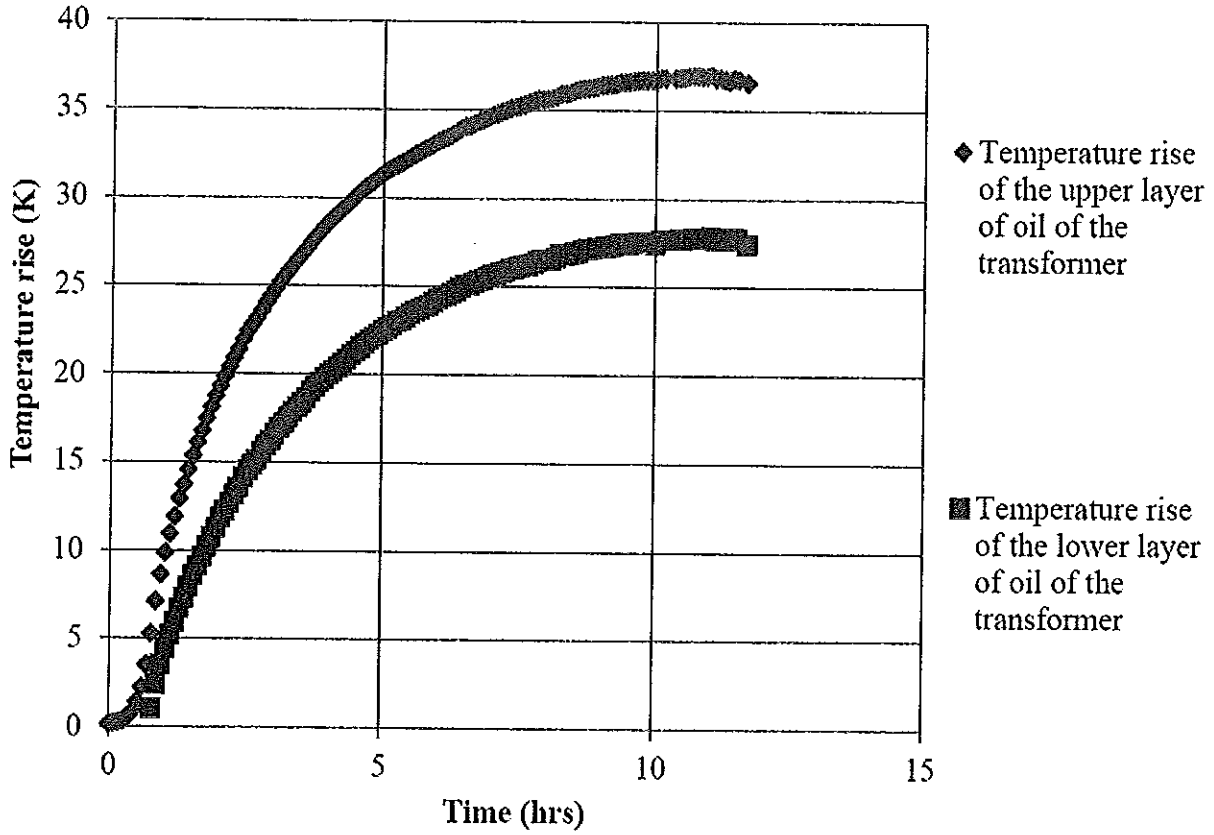


Fig. 3: Examples of temperature during the test.

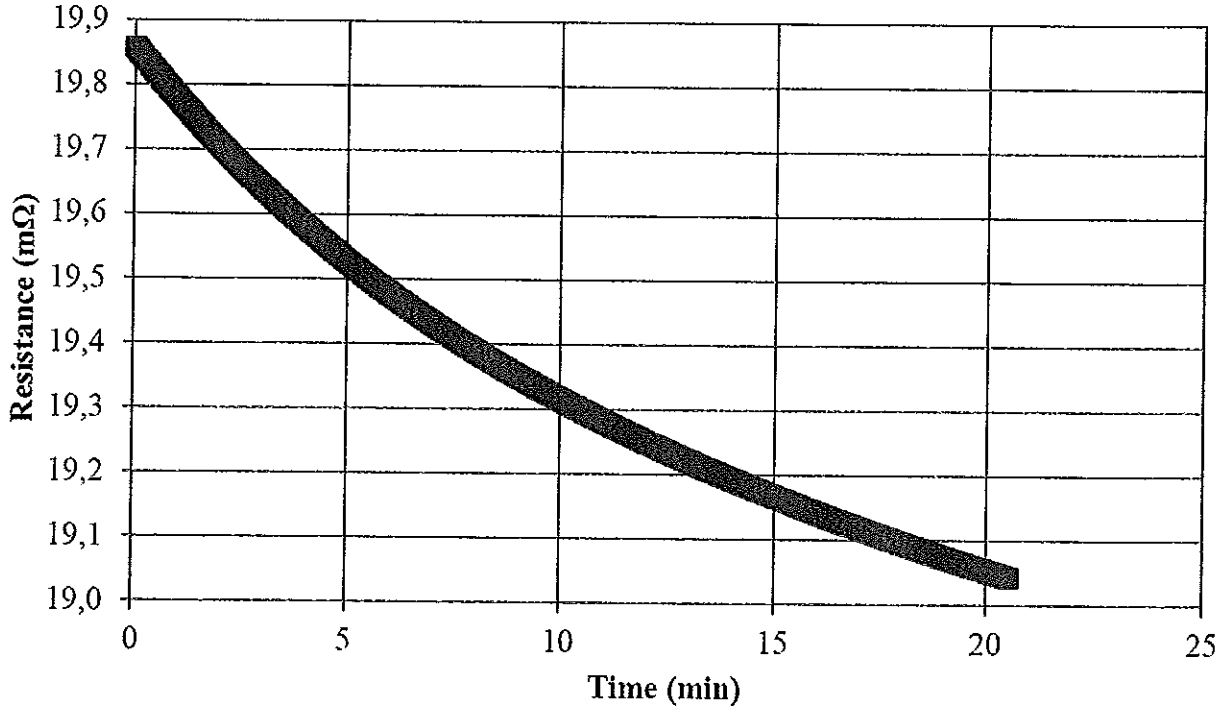


Fig. 4: Time development of interlaced and extrapolated resistances of the windings on the side of LV terminals after the temperature rise test.

		Temperature rise (K)	Limit (K)	Interpretation of test results
Temperature rise of the upper layer of oil		36.8	60	**Passed**
Middle temperature rise of the oil		32.2	--	--
Middle temperature rise of the winding	HV side	58.7	65	**Passed**
	LV side	50.8	65	**Passed**

Tab. 5: Temperature rise above ambient temperature, calculated by Standard ČSN EN 60076-2 ed.2. Uncertainty of temperature rise is maximally 1.2 K for oil measuring and 3.0 K for temperature rise test of winding. This uncertainty is calculated as product of standard uncertainty and coefficient "k", which corresponds to the interval of reliability circa 95%, which in case of standard distribution corresponds to coefficient k = 2.

Interpretation of the test results:

It is possible to certify according to the Standard ČSN EN 60076-2 ed.2, Clause. 7.11 „Uncertainties affecting the results of the temperature rise test", that the estimation of uncertainties should not be used for certification of specified limits gaining. Uncertainties should be used for information only.

Full wave lightning impulse test (LI)

Description

Full wave lightning impulse test was performed according to the Standard ČSN EN 60076-3 ed.2, Clause 13.2 at the principal tapping of the tested transformer with ratio 20/0.4 kV. The test was performed with standardized 1.2 μs $^{\pm 30\,\%}$/50 μs $^{\pm 20\,\%}$ lightning impulse of a negative polarity, **U** = 150 kV. The value of the testing voltage was chosen by the customer from the Standard ČSN EN 60076-3 ed.2, Table 2.

The test was performed for the following combination:

- 1 reference impulse (50 – 70% **U**),
- 3 impulses of 100 % **U** level.

This impulse combination was applied gradually to every phase terminal of the tested HV winding. The remaining phase terminals and the tank of the transformer were grounded. One additional measuring channel was used for the measurement of the current flowing from the remaining tw interconnected phase terminal to the ground.

The lighting impulse test was performed under the following atmospheric conditions:

- atmospheric pressure: 99.04 kPa,
- temperature: 19.1 °C.

Results

The following test division and classification of each oscillogram is related to numeration, indicated under each following oscillogram **No. 1 – 13** in **figs 5-8:.**

Shape of wave – oscillogram 1.
Reference impulse – oscillograms 2 (phase 1U), 6 (phase 1V) and 10 (phase 1W).
Phase 1U – oscillograms 3, 4 and 5.
Phase 1V – oscillograms 7, 8 and 9.
Phase 1W – oscillograms 11, 12 and 13.

Interpretation of the test results:

It is evident (oscillograms in **fig. 5 - 8**) that the insulation of the tested transformer passed the lightning impulse tests (LI).

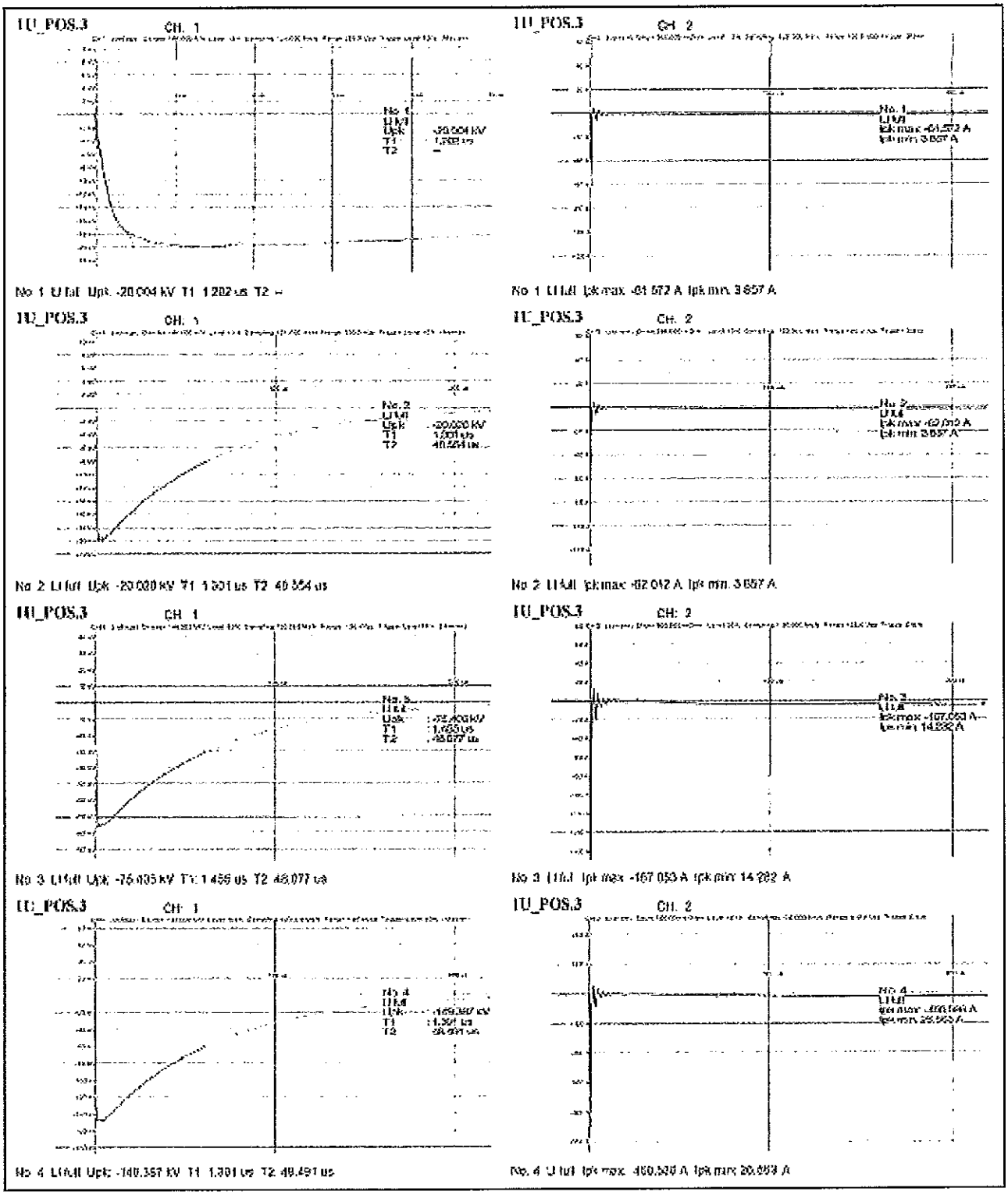


Fig. 5: Lighting impulse test.

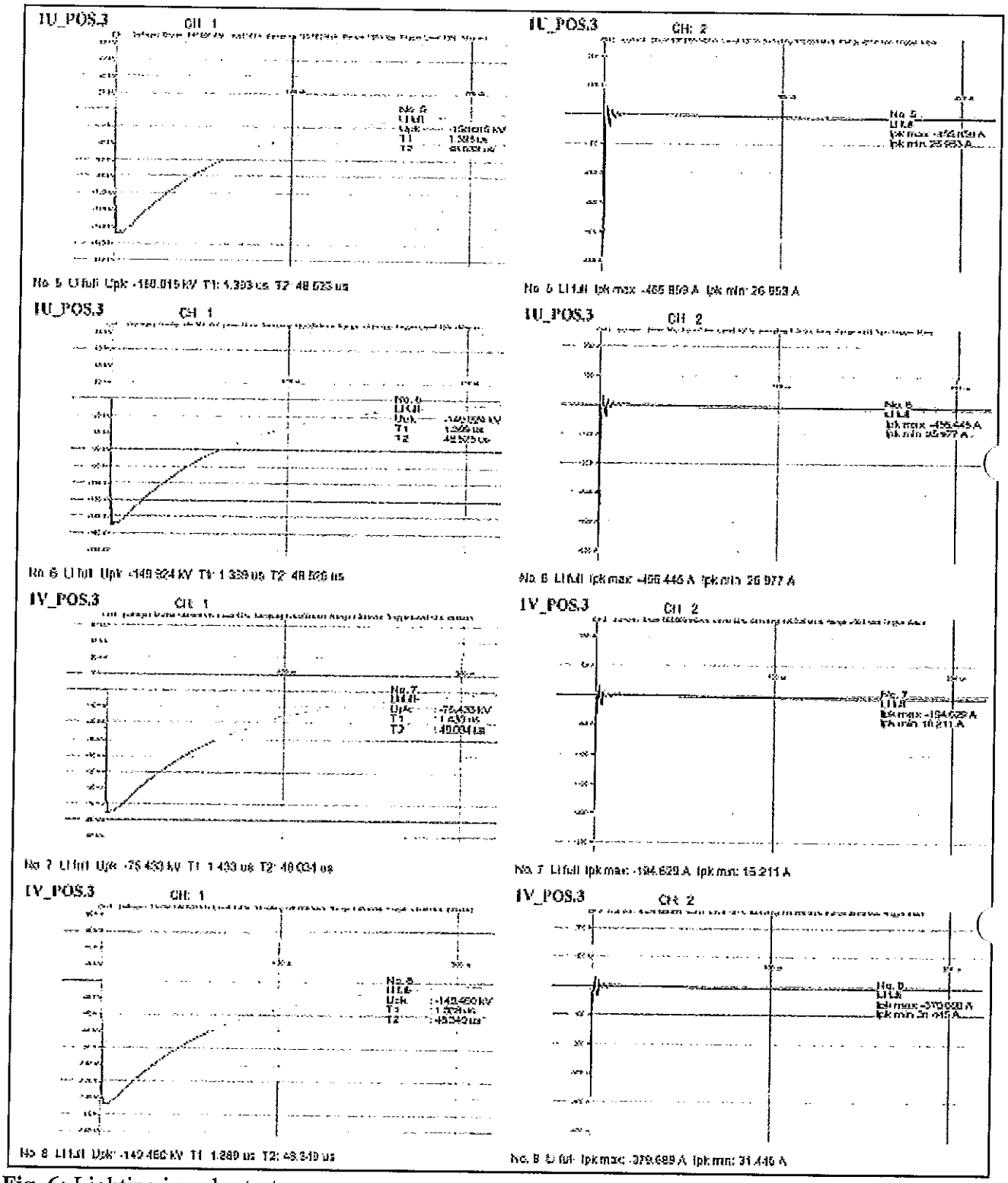


Fig. 6: Lighting impulse test.

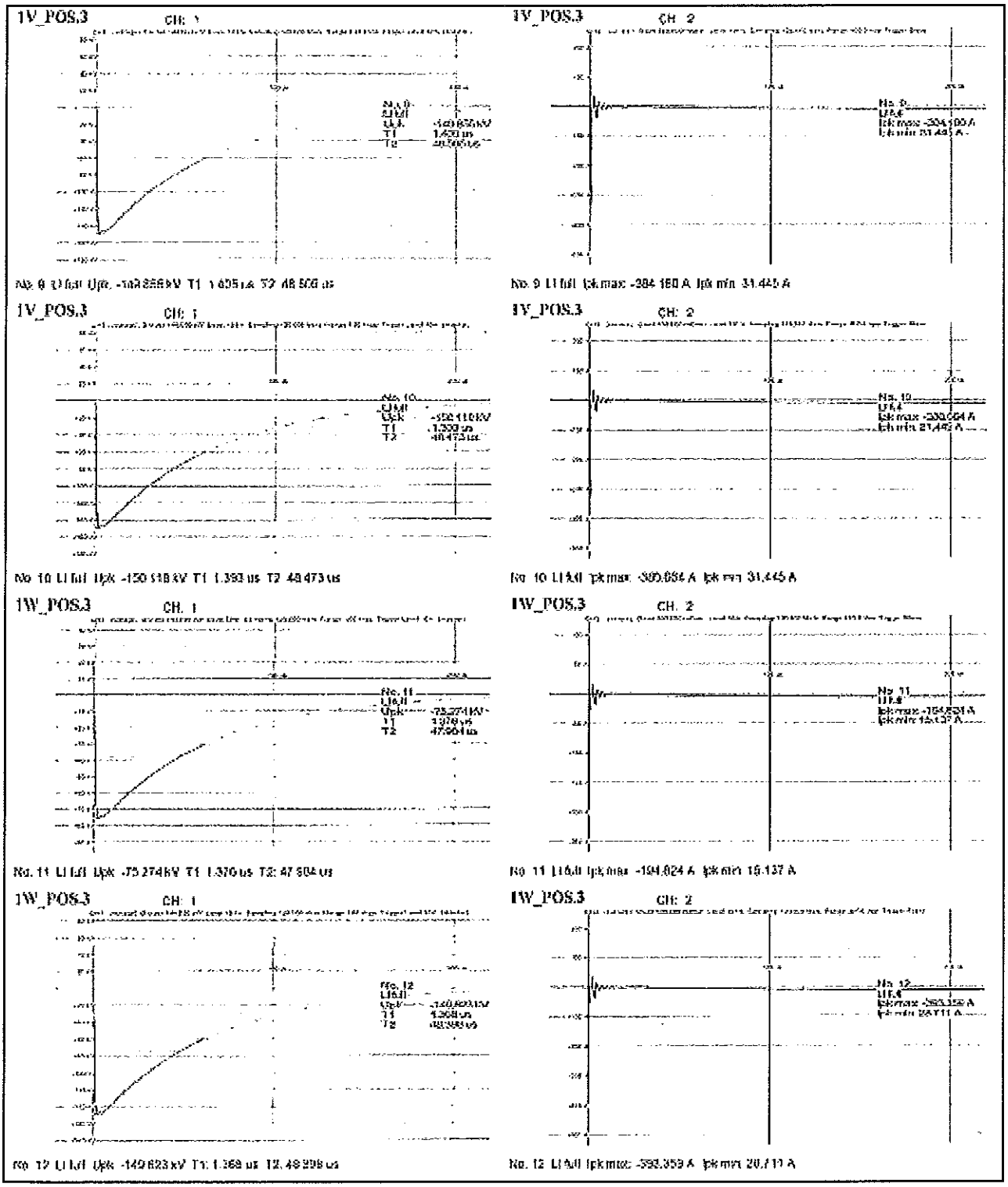


Fig. 7: Lighting impulse test.

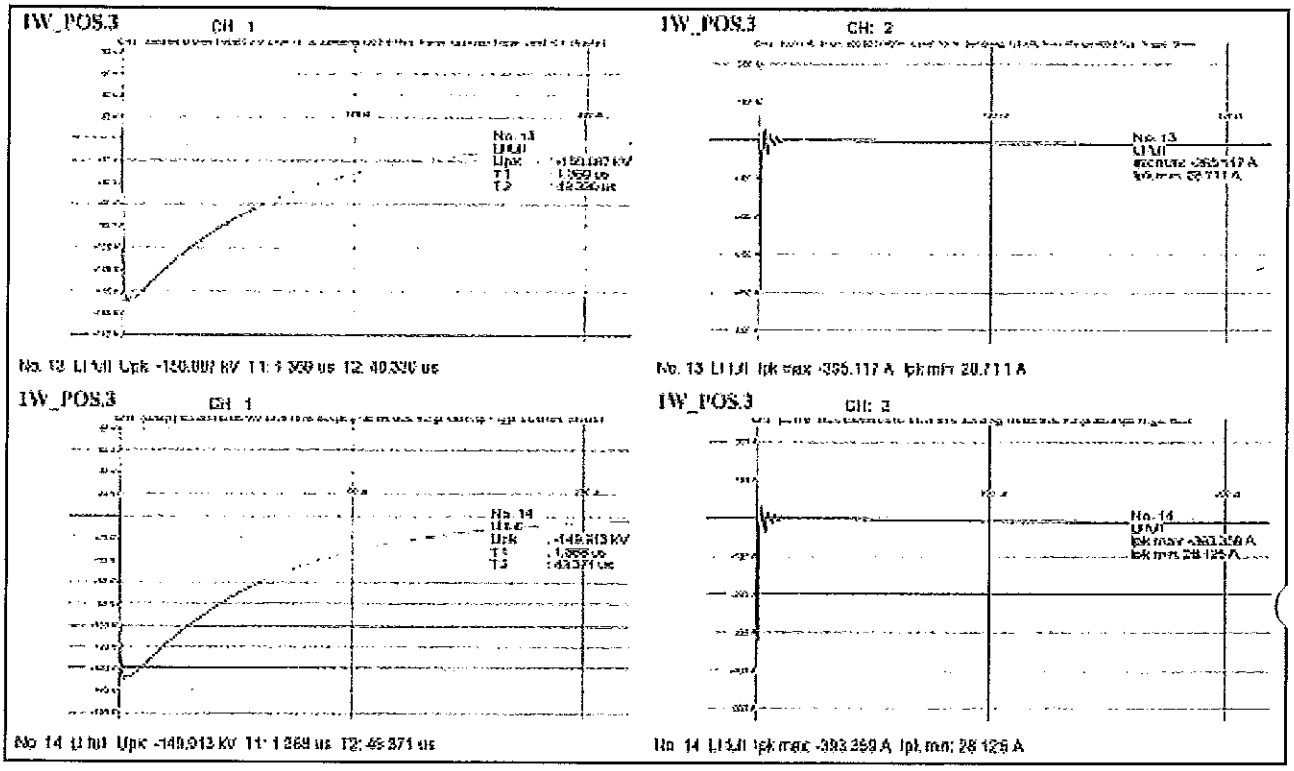


Fig. 8: Lighting impulse test.

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issues

according to section 16 of Act No. 22/1997 Coll., on technical requirements for products, as amended

CERTIFICATE OF ACCREDITATION

No. 660 / 2015

ETD TRANSFORMÁTORY a.s.
with registered office Zborovská 54/22, 301 00 Plzeň, Company Registration No. 25137808

to the Testing Laboratory No. 1526
ELECTRICAL TESTING LABORATORY

Scope of accreditation:

Electrical and air-handling testing and measuring of industrial equipment to the extent as specified in the appendix to this Certificate.

This Certificate of Accreditation is a proof of Accreditation issued on the basis of assessment of fulfillment of the accreditation criteria in accordance with

ČSN EN ISO/IEC 17025:2005

In its activities performed within the scope and for the period of validity of this Certificate, the Body is entitled to refer to this Certificate, provided that the accreditation is not suspended and the Body meets the specified accreditation requirements in accordance with the relevant regulations applicable to the activity of an accredited Conformity Assessment Body.

This Certificate of Accreditation replaces, to the full extent, Certificate No.: 474/2014 of 15 July 2014, or any administrative acts building upon it

The Certificate of Accreditation is valid until: **1 July 2018**

Prague: 21 September 2015

Jiří Růžička
Director
Czech Accreditation Institute
Public Service Company

- 2 -

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L 1526

Total sheets: 14

Test Report

AP_EZ/2016/049/01/EN

Customer:	BEZ TRANSFORMÁTORY a.s. Rybničná 40 835 54 Bratislava
Tested object:	**Transformer TOHn 359/22, s.n. 0363336**
Test take over date:	September 23th , 2016
Test realization date:	September 28th , 2016
Test identification No.:	365-302-1624 **Evidentiary No:** 48/2016
Order No:	B06/4500006720

Testing methods, regulations:

ACCREDITED TESTS ACCORDING TO SOP_EZ/2, 4, 6 and 8:

ČSN EN 60076-1, Clause 11.2	Measurement of winding resistance
ČSN EN 60076-1, Clause 11.4	Measurement of short-circuit impedance and load loss
ČSN EN 60076-1, Clause 11.5	Measurement of no-load loss and current
ČSN EN 60076-2 ed.2	Power transformer – Part 2: Temperature rise for liquid-immersed transformers
ČSN EN 60076-3 ed.2, Clause 13.2	Full wave lightning impulse test (LI)

Test results: In the text.

Enclosures: --

In Plzeň, 30th September 2016

Petr Šíma
Electrical Testing Laboratory Director

Test Report is issued in 3 copies – 2 are obtained by the customer and 1 is kept in the Laboratory.
Test Report is issued for the customer in electronic form too.

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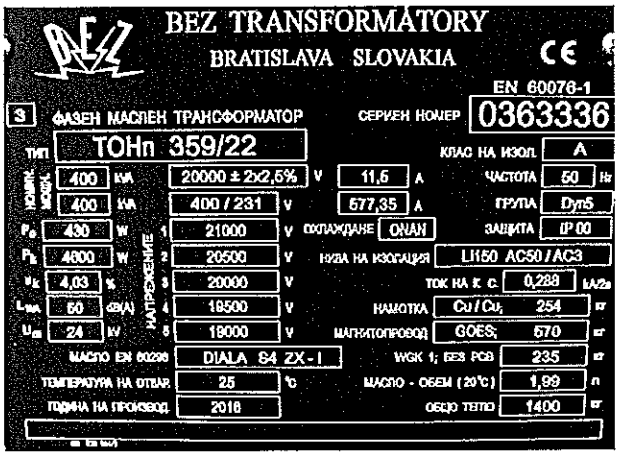
Tested object

Oil-immersed transformer TOHn 359/22.



Performed tests

Routine tests:

- Measurement of winding resistance according to the Standard ČSN EN 60076-1, Clause 11.2. The test was carried out at tappings 1, 3 and 5 of the tested transformer.
- Measurement of short-circuit impedance and load loss according to the Standard ČSN EN 60076-1, Clause 11.4. The test was carried out at tappings 1, 3 and 5 of the tested transformer.
- Measurement of no-load loss and current according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the tested transformer.

Type tests:

- Temperature rise test according to the Standard ČSN EN 60076-2 ed.2 at tapping 3 of the tested transformer with ratio 20/0.4 kV.
- Full wave lightning impulse test (LI) of the tested transformer according to the Standard ČSN EN 60076-3 ed.2, Clause 13.2. Test was carried out at HV side with negative wave 150 kV.

Used apparatuses

Name	Type	Filing No.
Digital multimeter	Fluke 189	PMMm 263
Digital multimeter	Fluke 179	PMMm 269
Digital oscilloscope	AT DSO7034A	PMMo 265
Digital oscilloscope	Keysight DSO-X 4034A	PMMo 270
Isolating converters	BB3652	PMMp 254
Mercury thermometer	from 0°C to 50°C	PMMt 239
Digital thermometer	GMH 3710	PMMt 268
Current transformer	ABB Petercem EA100	PMTr 92
Current transformer	ABB Petercem EA100	PMTr 93
Current transformer	ABB Petercem EA100	PMTr 94
Three-phase power analyzer	D6100	PMWa 19
Power analyzer	Norma 5000	PMWa 27
Impulse Analyzing System	HiAS 743	176736

Measurement of winding resistance

Description

The measurement of winding resistance was performed according to the Standard ČSN EN 60076-1, Clause 11.2.3. Measurement was carried out at tappings 1, 3 and 5 of the tested transformer in temperature steady state.

Winding resistances each of above mentioned tappings were measured with DC current, with Ohm's method, between terminals of each phase on HV side of transformer and between node and terminal of respective phase on LV side of tested transformer. The mean temperature of cooling liquid (temperature of transformer winding) was measured during the test. Temperature was between 22.3 °C and 22.7 °C. Resulting value of the resistance was recalculated to 75 °C.

Results

Resistances of transformer winding are noted in **Tab. 1.**

Side of transformer	Tap	Terminal	Before type and special tests	
			$R_{measured}$ (Ω)	R_{75} (Ω)
HV	1 (+ 5 %)	1U – 1V	9.636676126	11.61045316
		1U – 1W	9.680634743	11.66341535
		1V – 1W	9.660335285	11.63895817
	3 (0 %)	1U – 1V	9.129011656	10.99880922
		1U – 1W	9.165738826	11.04305883
		1V – 1W	9.155209410	11.03037278
	5 (- 5 %)	1U – 1V	8.623641358	10.38992935
		1U – 1W	8.662324251	10.43653524
		1V – 1W	8.598903282	10.36012444
LV		2n – 2u	0.001932286	0.002326247
		2n – 2v	0.001916093	0.002307650
		2n – 2w	0.001916987	0.002308726

Tab. 1: Resistances of transformer winding.

Measurement of short-circuit impedance and load loss

Description

Measurement of short-circuit impedance and load loss was performed according to the Standard ČSN EN 60076-1, Clause 11.4. The test was carried out at tappings 1, 3 and 5 of the tested transformer in temperature steady state.

Voltage was applied to HV terminals of the transformer, LV terminals were short circuited. Supply current of 50 Hz was ca. 4 A. Temperature was 22.5 °C.

Measured values of short-circuit impedance and load loss were corrected for the reference temperature 75 °C.

Results

Measured values of short-circuit impedance and load loss are noted in **Tab. 2.**

	Z a Δ P_k		
Tapping	1 (+ 5 %)	3 (0 %)	5 (- 5 %)
$Z_{measured}$ (Ω)	44.52	40.24	35.60
Z_{75} (Ω)	44.93	40.71	36.17
$\Delta P_{k\ measured}$ (W)	3 217.76	3 871.41	4 650.32
$\Delta P_{k\ 75}$ (W)	3 953.37	4 570.21	5 342.73

Tab. 2: Values of the short-circuit impedance and load loss.

Measurement of no-load loss and currents

Description

Measurement of no-load losses and currents was performed according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the tested transformer in temperature steady state.

Supply voltage was applied to LV terminals of the transformer; HV terminals were no-loaded. Supply voltage during the measurement was set to 90 %, 100 % and 110 % of rated voltage U_2.

Results

Measured values of no-load losses and currents are noted in **tab. 3** and **4**.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
Δ P_0 (W)	328.0	421.4	546,6

Tab. 3: Values of the no-load losses.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
I_0 (A)	1.0247	1.1057	1.4079

Tab. 4: Values of the no-load currents.

Temperature rise test

Description

Short-circuit method was used. Transformer was connected to the testing circuit according to the **fig. 1**. Lead-in copper cables 16 mm^2 on the side of HV terminals and copper pas with dimension ca. 800 mm^2 on the side of LV terminals were used. Frequency of power source was **f** = 50 Hz.

Mean temperature of the side of the HV and LV winding was determined by measuring of electrical resistance of the winding. Wiring is shown in **fig. 2**. The resistance was measured by Ohm´s method on both sides. At the end of the test, the time development of the resistance was recorded from the moment after switching circuits and electrical stabilization of the measuring circuit. The development was extrapolated to the moment when testing current was switched off.

Other temperatures were measured by thermocouples in connection with a measuring system. Oil temperature was measured in the oil sump at the top of the transformer. Side surface temperature was measured in eight points, four ones up and four ones down, close to corners of the transformer container. These values were used to calculate the temperature of the middle oil layer.

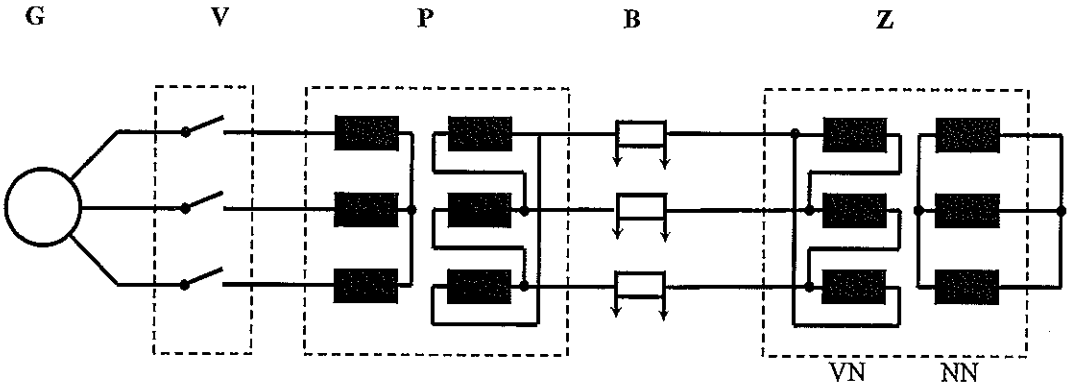
Ambient temperature was measured in four points, approximately 2 m distant from the transformer, in one half of its height. Mean value was used to process results.

The test was divided into two parts. The first one was designated for measurement of the oil temperature rise above ambient. The second one was designated for measurement of the winding temperature rise above oil.

In the first part the transformer was loaded by a current (slightly higher than the nominal one) which generated the total losses (no-load losses plus short-circuit losses) 5 022,3 W in the transformer. The losses were measured on the HV terminals side. The losses were kept constant during the test, while the current slightly changed. When oil temperature became steady, the temperature of the middle oil layer was determined.

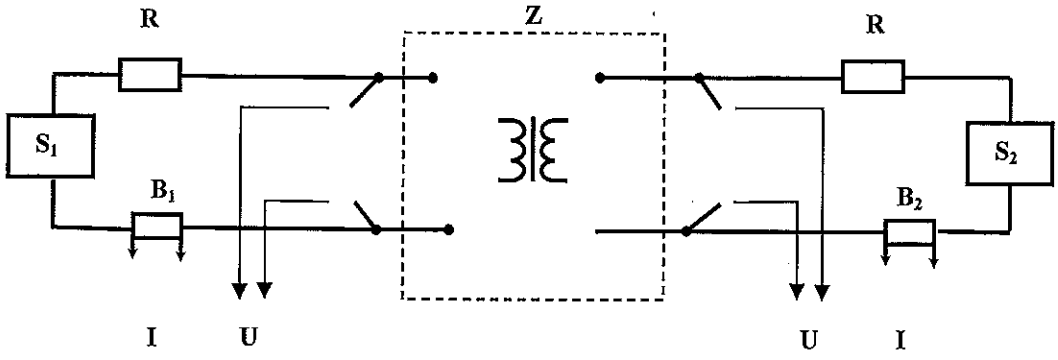
In the second part of the test the transformer was loaded by its nominal current **I** = 11.55 A for 1 hour. At the end the mean temperature of the winding and the temperature of the middle oil layer were determined.

Fig. 1: Measuring stand.



G	Generator 800 kVA,	**V**	generator breaker,
P	auxiliary transformer,	**B**	shunt for current measurement,
Z	tested transformer.		

Fig. 2: Testing power circuit for the temperature rise test.



Z	Tested transformer,	**S_1, S_2**	stabilized source of DC,
B_1, B_2	shunts for current measurement,	**R**	stabilizing resistors.

Fig. 5: Circuit for resistance measurement, arrows shows the connection to the measuring system.

Results

The test lasted 11.4 hours and it was finished according to Standard ČSN EN 60076-2 ed.2, Clause 7. Examples of time development of temperature are shown in **fig. 3**. Example of time development of interlaced and extrapolated resistance of the winding, connected to the LV and HV terminals, after the temperature rise test, are shown in **fig. 4**. Measured values of the resistance of the winding were extrapolated to the end of the temperature rise test. Recalculation between the resistances of the winding to the temperature was made by formula:

$$\Theta_2 = R_2 / R_1 \cdot (235 + \Theta_1) - 235$$

Θ_2 – temperature at the end of the test; Θ_1 – temperature before the test; R_2 – resistance of the winding at the end of the test; R_1 – resistance of the winding before the test.

Final results of temperature rise test are presented in **tab. 5.**

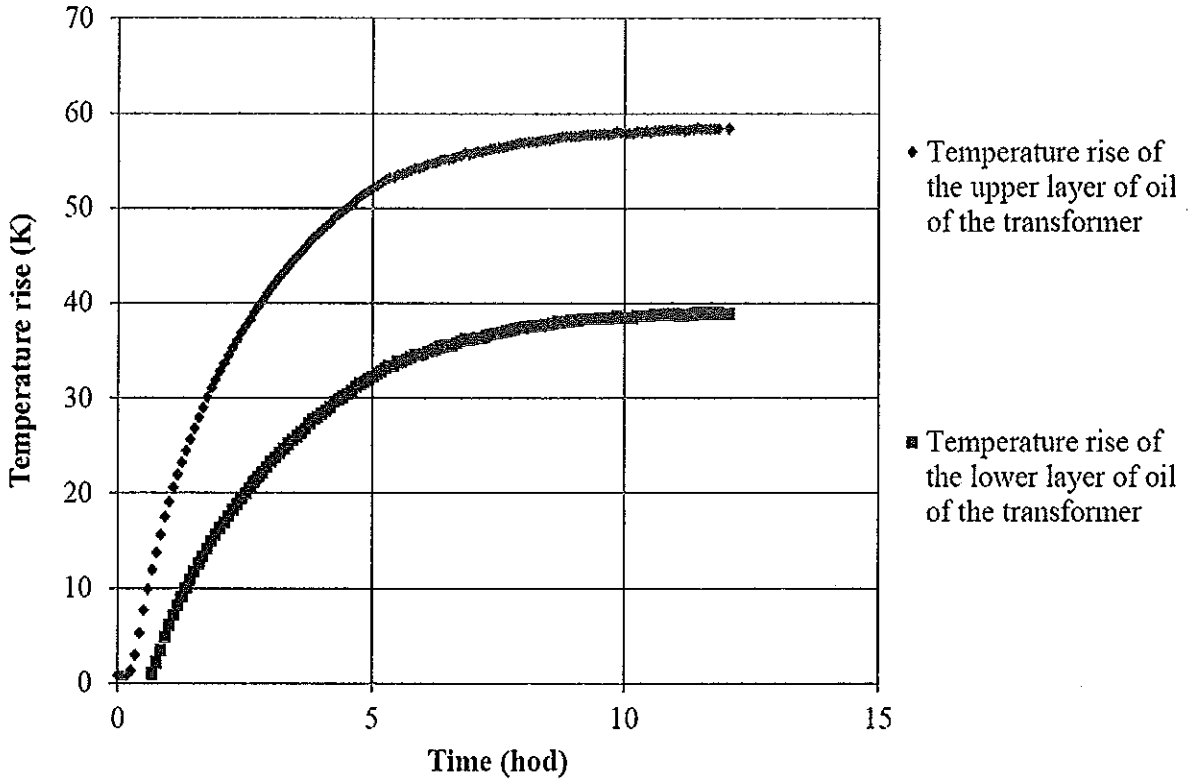


Fig. 3: Examples of temperature during the test.

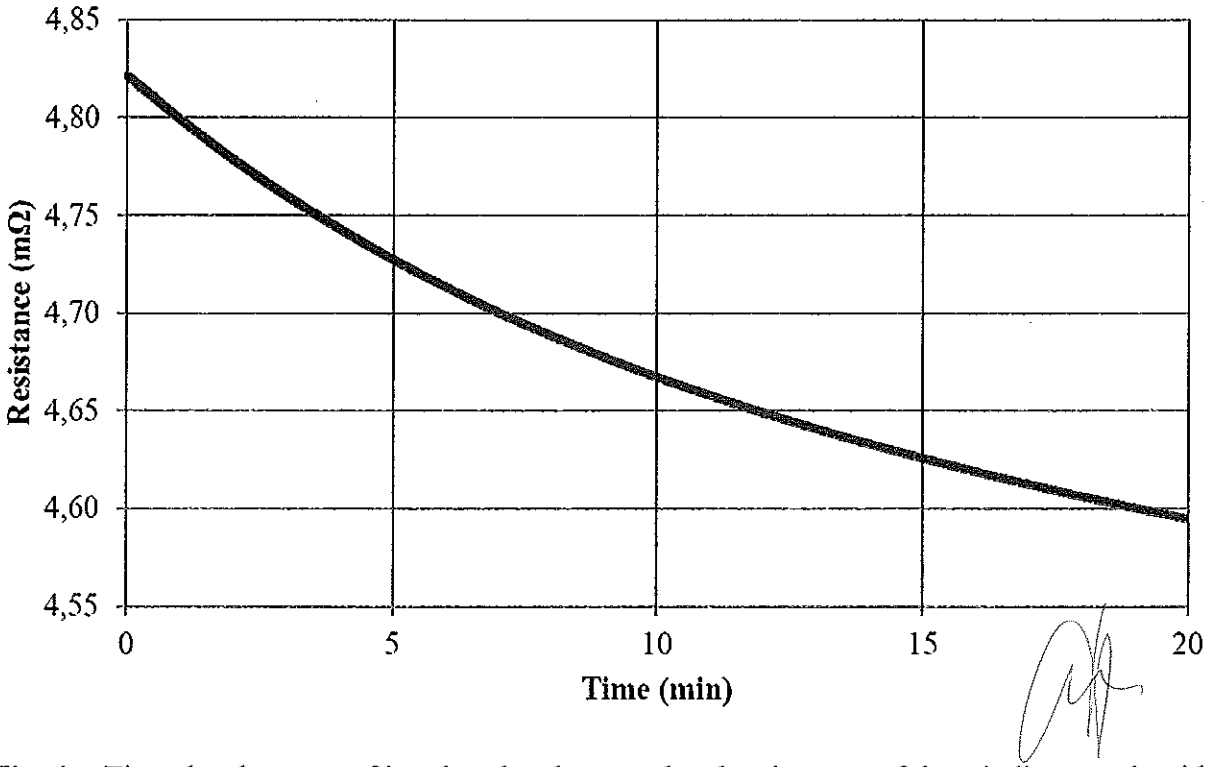


Fig. 4: Time development of interlaced and extrapolated resistances of the windings on the side of LV terminals after the temperature rise test.

		Temperature rise (K)	Limit (K)	Interpretation of test results
Temperature rise of the upper layer of oil		58.0	60	**Passed**
Middle temperature rise of the oil		48.3	--	--
Middle temperature rise of the winding	HV side	63.4	65	**Passed**
	LV side	64.8	65	**Passed**

Tab. 5: Temperature rise above ambient temperature, calculated by Standard ČSN EN 60076-2 ed.2. Uncertainty of temperature rise is maximally 1.2 K for oil measuring and 3.0 K for temperature rise test of winding. This uncertainty is calculated as product of standard uncertainty and coefficient "k", which corresponds to the interval of reliability circa 95%, which in case of standard distribution corresponds to coefficient k = 2.

Interpretation of the test results:

It is possible to certify according to the Standard ČSN EN 60076-2 ed.2, Clause. 7.11 „Uncertainties affecting the results of the temperature rise test", that the estimation of uncertainti(should not be used for certification of specified limits gaining. Uncertainties should be used for information only.

Full wave lightning impulse test (LI)

Description

Full wave lightning impulse test was performed according to the Standard ČSN EN 60076-3 ed.2, Clause 13.2 at the principal tapping of the tested transformer with ratio 20/0.4 kV. The test was performed with standardized 1.2 μs $^{\pm 30\,\%}$/50 μs $^{\pm 20\,\%}$ lightning impulse of a negative polarity, **U** = 150 kV. The value of the testing voltage was chosen by the customer from the Standard ČSN EN 60076-3 ed.2, Table 2.

The test was performed for the following combination:

- 1 reference impulse (50 – 70% **U**),
- 3 impulses of 100 % **U** level.

This impulse combination was applied gradually to every phase terminal of the tested HV winding. The remaining phase terminals and the tank of the transformer were grounded. One additional measuring channel was used for the measurement of the current flowing from the remaining two interconnected phase terminal to the ground.

The lighting impulse test was performed under the following atmospheric conditions:

- atmospheric pressure: 99.33 kPa,
- temperature: 19.5 °C.

Results

The following test division and classification of each oscillogram is related to numeration, indicated under each following oscillogram **No. 1 – 13** in **figs 5-8:.**

Shape of wave – oscillogram 1.
Reference impulse – oscillograms 2 (phase 1U), 6 (phase 1V) and 10 (phase 1W).
Phase 1U – oscillograms 3, 4 and 5.
Phase 1V – oscillograms 7, 8 and 9.
Phase 1W – oscillograms 11, 12 and 13.

Interpretation of the test results:

It is evident (oscillograms in **fig. 5 - 8**) that the insulation of the tested transformer passed the lightning impulse tests (LI).

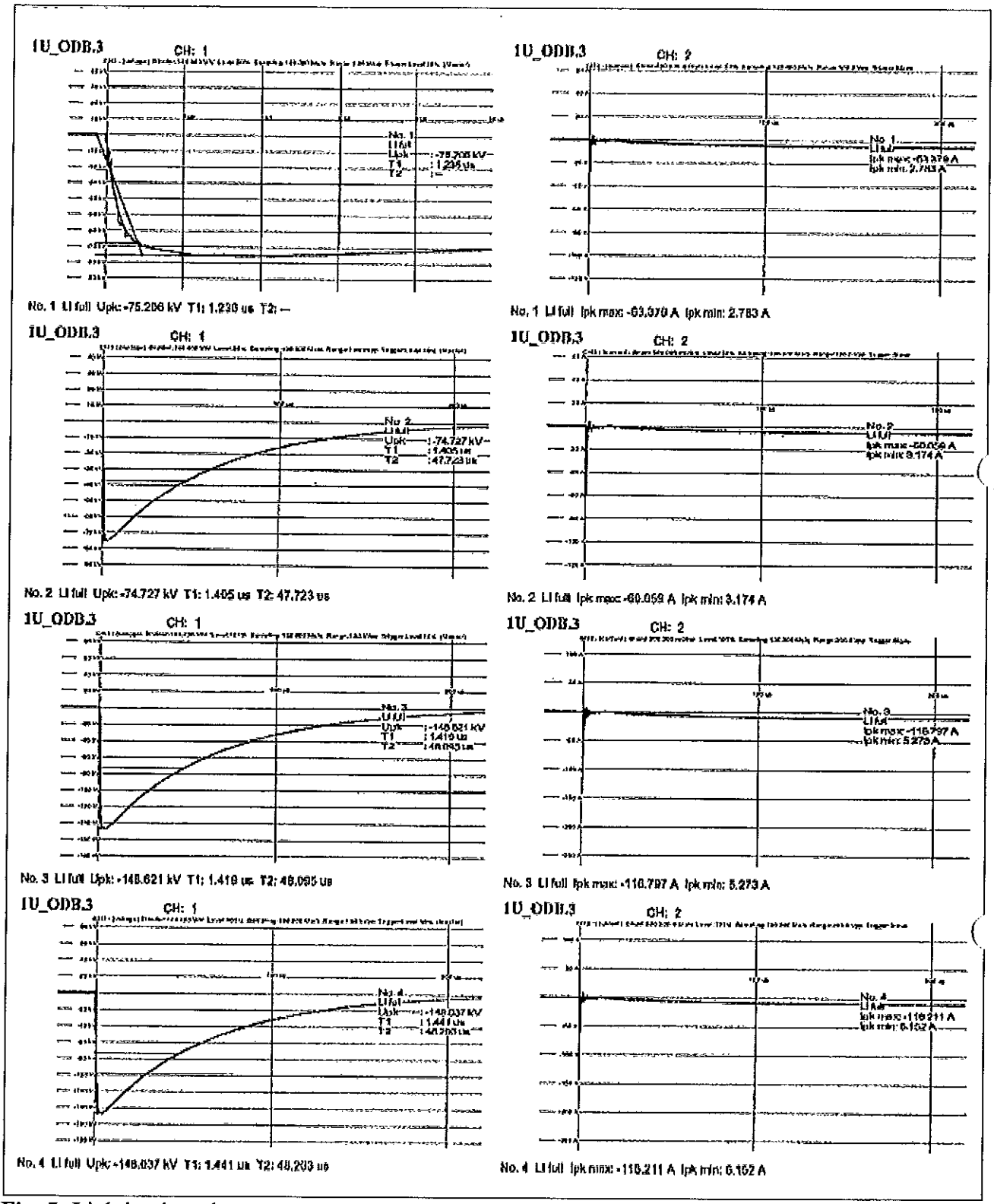


Fig. 5: Lighting impulse test.

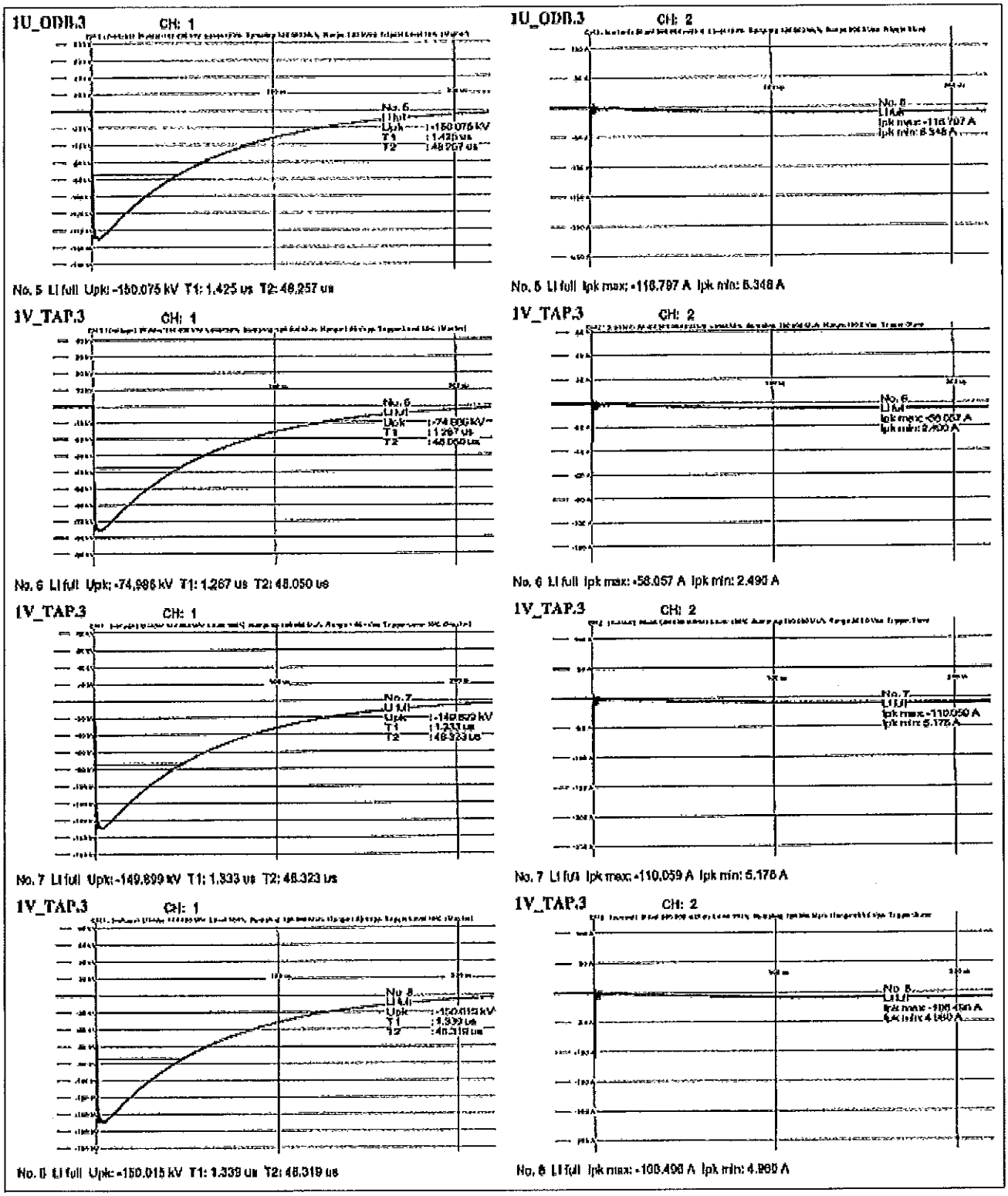


Fig. 6: Lighting impulse test.

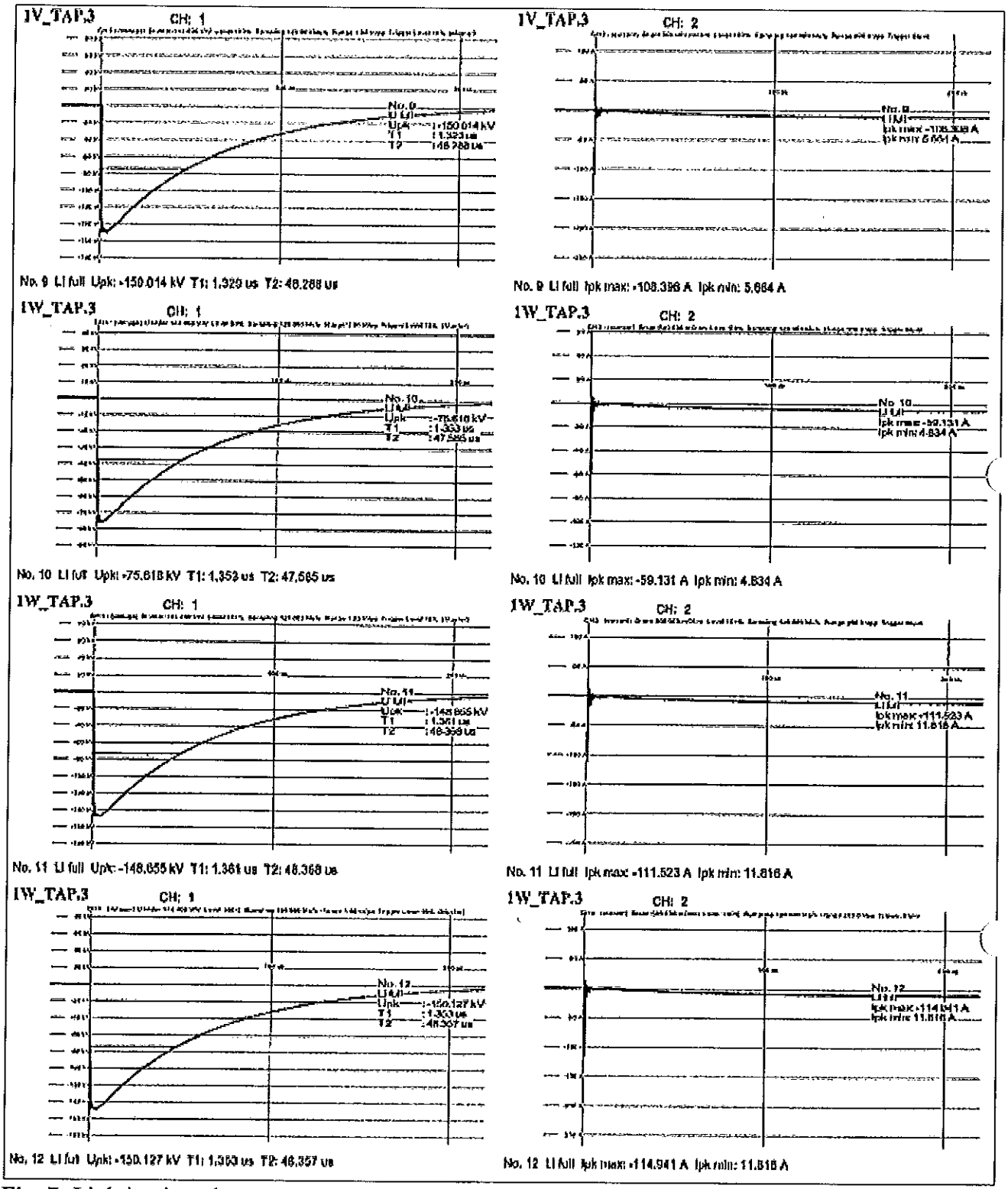


Fig. 7: Lighting impulse test.

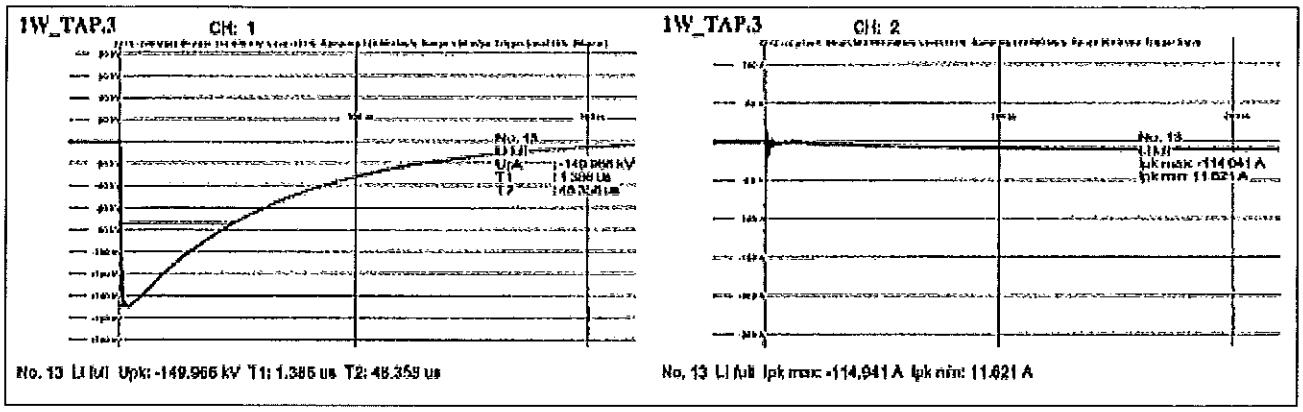


Fig. 8: Lighting impulse test.

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Olšanská 54/3, 130 00 Praha 3

issues

according to section 16 of Act No. 22/1997 Coll., on technical requirements for products, as amended

CERTIFICATE OF ACCREDITATION

No. 660 / 2015

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ELECTRICAL TESTING LABORATORY

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The Certificate of Accreditation is valid until: **1 July 2018**

Prague: 21 September 2015

Jiří Růžička
Director
Czech Accreditation Institute
Public Service Company

Methods used in testing are specified in the Quality Manual of the Electrical Testing Laboratory and satisfy the precision requirements according to the respective standards. The presented test results are in relation to the subject of these tests only. The Test Report may be reproduced only as a whole.
In case of discrepancies the Czech version of the Test Report takes precedence.

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ELEKTROTECHNICKÁ ZKUŠEBNA
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L 1526

Total sheets: 13

Test Report

AP_EZ/2016/051/01/EN

Customer:	BEZ TRANSFORMÁTORY a.s. Rybničná 40 835 54 Bratislava
Tested object:	**Transformer TOHn 389/22, s.n. 0361831**
Test take over date:	September 23th , 2016
Test realization date:	September 30th , 2016
Test identification No.:	365-302-1624 **Evidentiary No:** 48/2016
Order No:	B06/4500006720

Testing methods, regulations:

ACCREDITED TESTS ACCORDING TO SOP_EZ/2, 4, 6 and 8:

ČSN EN 60076-1, Clause 11.2	Measurement of winding resistance
ČSN EN 60076-1, Clause 11.4	Measurement of short-circuit impedance and load loss
ČSN EN 60076-1, Clause 11.5	Measurement of no-load loss and current
ČSN EN 60076-2 ed.2	Power transformer – Part 2: Temperature rise for liquid-immersed transformers
ČSN EN 60076-3 ed.2, Clause 13.2	Full wave lightning impulse test (LI)

Test results: In the text.

Enclosures: --

In Plzeň, 30th September 2016

Petr Šíma
Electrical Testing Laboratory Director

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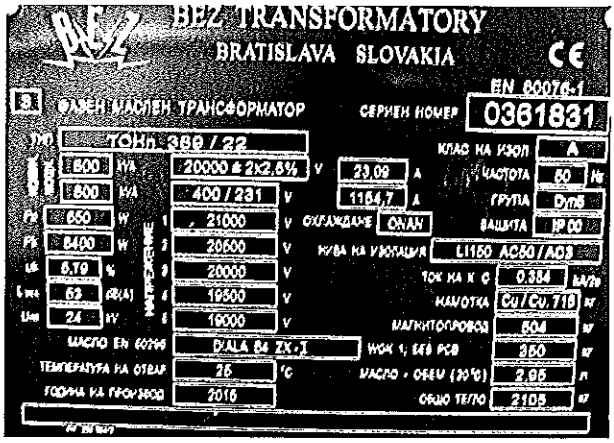
Description 8
Results 8

Tested object

Oil-immersed transformer TOHn 389/22.



Performed tests

Routine tests:

- Measurement of winding resistance according to the Standard ČSN EN 60076-1, Clause 11.2. The test was carried out at tappings 1, 3 and 5 of the tested transformer.
- Measurement of short-circuit impedance and load loss according to the Standard ČSN EN 60076-1, Clause 11.4. The test was carried out at tappings 1, 3 and 5 of the tested transformer.
- Measurement of no-load loss and current according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the tested transformer.

Type tests:

- Temperature rise test according to the Standard ČSN EN 60076-2 ed.2 at tapping 3 of the tested transformer with ratio 20/0.4 kV.
- Full wave lightning impulse test (LI) of the tested transformer according to the Standard ČSN EN 60076-3 ed.2, Clause 13.2. Test was carried out at HV side with negative wave 150 kV.

Used apparatuses

Name	Type	Filing No.
Digital multimeter	Fluke 189	PMMm 263
Digital multimeter	Fluke 179	PMMm 269
Digital oscilloscope	AT DSO7034A	PMMo 265
Digital oscilloscope	Keysight DSO-X 4034A	PMMo 270
Isolating converters	BB3652	PMMp 254
Mercury thermometer	from 0°C to 50°C	PMMt 239
Digital thermometer	GMH 3710	PMMt 268
Current transformer	ABB Petercem EA100	PMTr 92
Current transformer	ABB Petercem EA100	PMTr 93
Current transformer	ABB Petercem EA100	PMTr 94
Three-phase power analyzer	D6100	PMWa 19
Power analyzer	Norma 5000	PMWa 27
Impulse Analyzing System	HiAS 743	176736

Measurement of winding resistance

Description

The measurement of winding resistance was performed according to the Standard ČSN EN 60076-1, Clause 11.2.3. Measurement was carried out at tappings 1, 3 and 5 of the tested transformer in temperature steady state.

Winding resistances each of above mentioned tappings were measured with DC current, with Ohm's method, between terminals of each phase on HV side of transformer and between node and terminal of respective phase on LV side of tested transformer. The mean temperature of cooling liquid (temperature of transformer winding) was measured during the test. Temperature was 22.5 °C. Resulting value of the resistance was recalculated to 75 °C.

Results

Resistances of transformer winding are noted in **Tab. 1.**

Side of transformer	Tap	Terminal	Before type and special tests	
			$R_{measured}$ (Ω)	R_{75} (Ω)
HV	1 (+ 5 %)	1U – 1V	4.130217695	4.972300915
		1U – 1W	4.122274221	4.962737897
		1V – 1W	4.131014447	4.973260110
	3 (0 %)	1U – 1V	3.907538807	4.704221476
		1U – 1W	3.898721044	4.693605917
		1V – 1W	3.905860784	4.702201332
	5 (- 5 %)	1U – 1V	3.686047671	4.437571954
		1U – 1W	3.678689180	4.428713187
		1V – 1W	3.686406004	4.438003344
LV		2n – 2u	0.000788773	0.000949591
		2n – 2v	0.000777999	0.000936620
		2n – 2w	0.000799017	0.000961923

Tab. 1: Resistances of transformer winding.

Measurement of short-circuit impedance and load loss

Description

Measurement of short-circuit impedance and load loss was performed according to the Standard ČSN EN 60076-1, Clause 11.4. The test was carried out at tappings 1, 3 and 5 of the tested transformer in temperature steady state.

Voltage was applied to HV terminals of the transformer, LV terminals were short circuited. Supply current of 50 Hz was ca. 13 A. Temperature was 22.7 °C.

Measured values of short-circuit impedance and load loss were corrected for the reference temperature 75 °C.

Results

Measured values of short-circuit impedance and load loss are noted in **Tab. 2.**

	Z a Δ P_k		
Tapping	1 (+ 5 %)	3 (0 %)	5 (- 5 %)
$Z_{measured}$ (Ω)	32.70	28.82	25.49
Z_{75} (Ω)	32.79	28.94	25.62
$\Delta P_{k\ measured}$ (W)	5 745.95	6 885.53	8 291.65
$\Delta P_{k\ 75}$ (W)	6 900.20	7 998.12	9 372.92

Tab. 2: Values of the short-circuit impedance and load loss.

Measurement of no-load loss and currents

Description

Measurement of no-load losses and currents was performed according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the tested transformer in temperature steady state.

Supply voltage was applied to LV terminals of the transformer; HV terminals were no-loaded. Supply voltage during the measurement was set to 90 %, 100 % and 110 % of rated voltage U_2.

Results

Measured values of no-load losses and currents are noted in **tab. 3** and **4**.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
Δ P_0 (W)	478.1	643.8	869.4

Tab. 3: Values of the no-load losses.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
I_0 (A)	1.0976	1.7373	6.5700

Tab. 4: Values of the no-load currents.

Temperature rise test

Description

Short-circuit method was used. Transformer was connected to the testing circuit according to the **fig. 1**. Lead-in copper cables 16 mm^2 on the side of HV terminals and copper pas with dimension ca. 800 mm^2 on the side of LV terminals were used. Frequency of power source was **f** = 50 Hz.

Mean temperature of the side of the HV and LV winding was determined by measuring of electrical resistance of the winding. Wiring is shown in **fig. 2**. The resistance was measured by Ohm´s method on both sides. At the end of the test, the time development of the resistance was recorded from the moment after switching circuits and electrical stabilization of the measuring circuit. The development was extrapolated to the moment when testing current was switched off.

Other temperatures were measured by thermocouples in connection with a measuring system. Oil temperature was measured in the oil sump at the top of the transformer. Side surface temperature was measured in eight points, four ones up and four ones down, close to corners of the transformer container. These values were used to calculate the temperature of the middle oil layer.

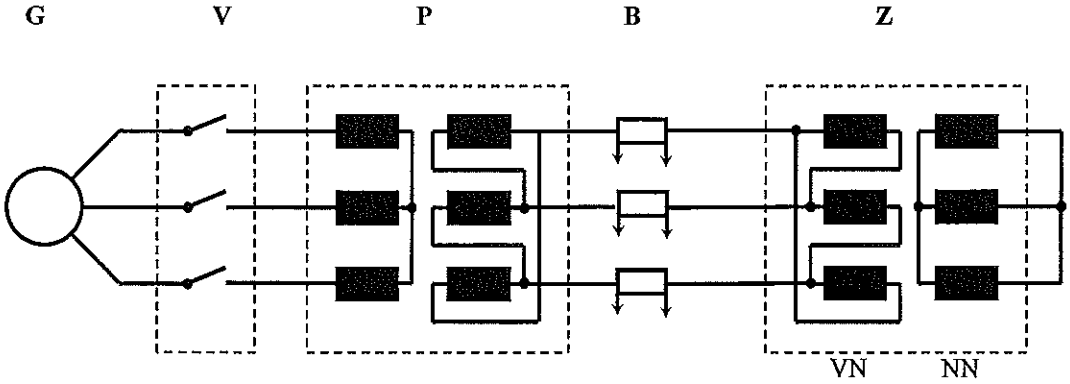
Ambient temperature was measured in four points, approximately 2 m distant from the transformer in one half of its height. Mean value was used to process results.

The test was divided into two parts. The first one was designated for measurement of the oil temperature rise above ambient. The second one was designated for measurement of the winding temperature rise above oil.

In the first part the transformer was loaded by a current (slightly higher than the nominal one) which generated the total losses (no-load losses plus short-circuit losses) 8 631,1 W in the transformer. The losses were measured on the HV terminals side. The losses were kept constant during the test, while the current slightly changed. When oil temperature became steady, the temperature of the middle oil layer was determined.

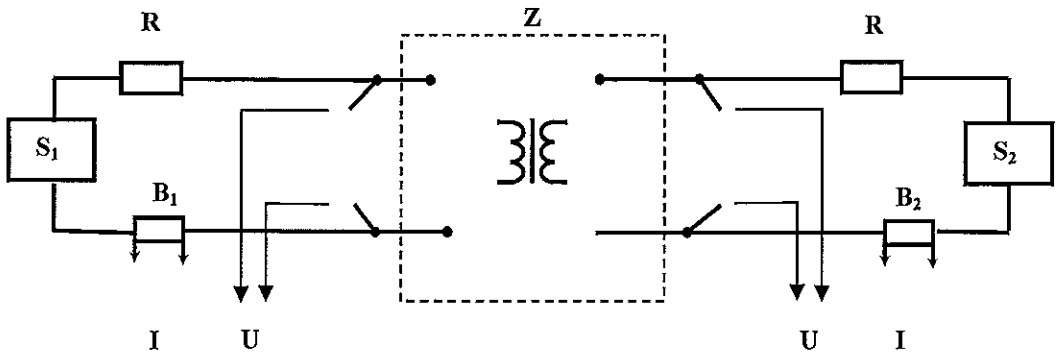
In the second part of the test the transformer was loaded by its nominal current **I** = 23.09 A for 1 hour. At the end the mean temperature of the winding and the temperature of the middle oil layer were determined.

Fig. 1: Measuring stand.



G	Generator 800 kVA,	**V**	generator breaker,
P	auxiliary transformer,	**B**	shunt for current measurement,
Z	tested transformer.		

Fig. 2: Testing power circuit for the temperature rise test.



Z	Tested transformer,	**S_1, S_2**	stabilized source of DC,
B_1, B_2	shunts for current measurement,	**R**	stabilizing resistors.

Fig. 5: Circuit for resistance measurement, arrows shows the connection to the measuring system.

Results

The test lasted 11,2 hours and it was finished according to Standard ČSN EN 60076-2 ed.2, Clause 7. Examples of time development of temperature are shown in **fig. 3**. Example of time development of interlaced and extrapolated resistance of the winding, connected to the LV and HV terminals, after the temperature rise test, are shown in **fig. 4**. Measured values of the resistance of the winding were extrapolated to the end of the temperature rise test. Recalculation between the resistances of the winding to the temperature was made by formula:

$$\Theta_2 = R_2 / R_1 \cdot (235 + \Theta_1) - 235$$

Θ_2 – temperature at the end of the test; Θ_1 – temperature before the test; R_2 – resistance of the winding at the end of the test; R_1 – resistance of the winding before the test.

Final results of temperature rise test are presented in **tab. 5**.

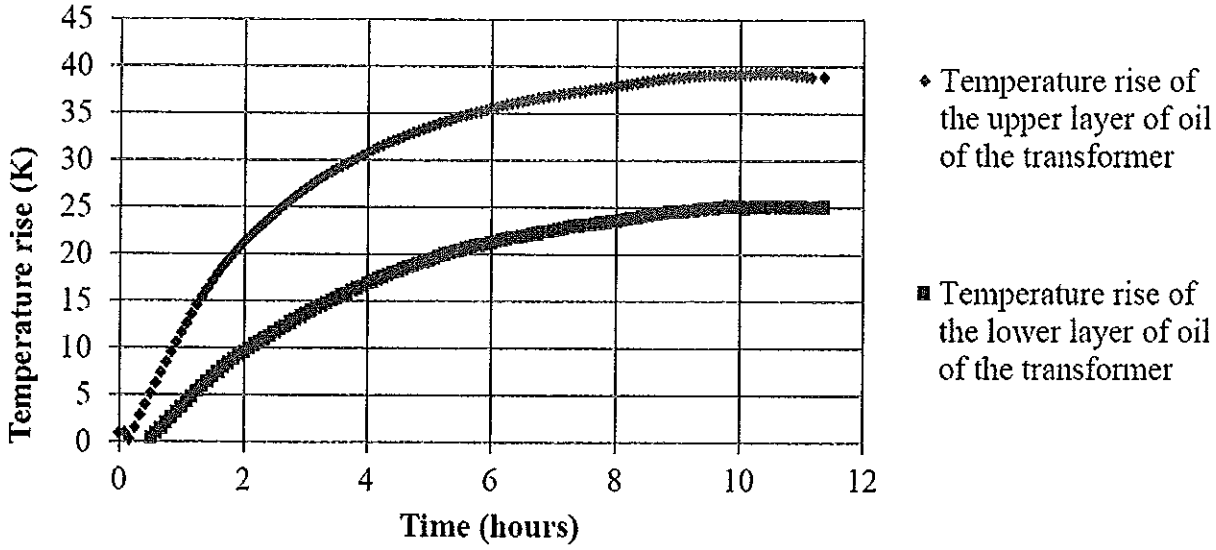


Fig. 3: Examples of temperature during the test.

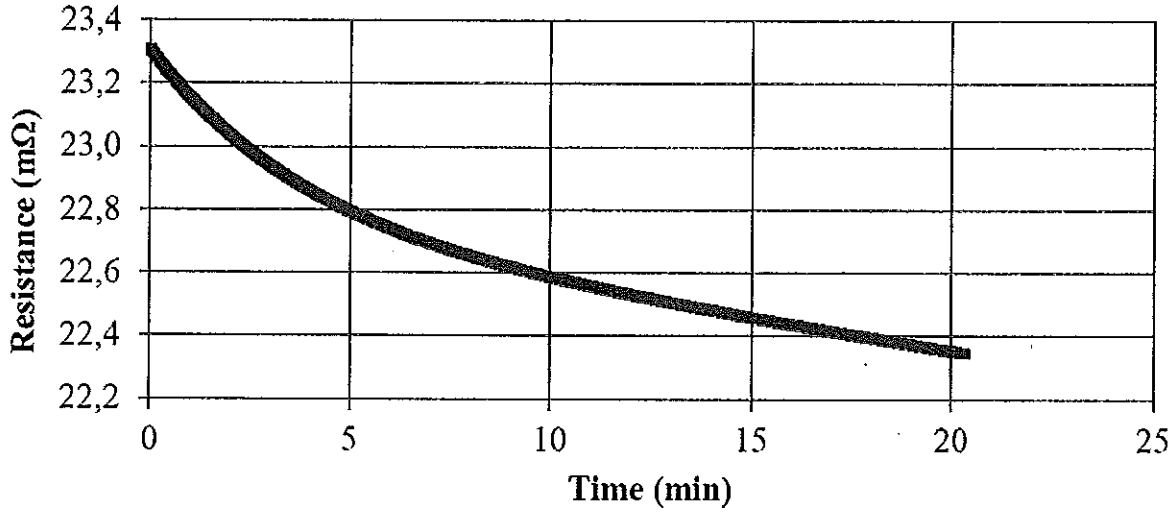


Fig. 4: Time development of interlaced and extrapolated resistances of the windings on the side of LV terminals after the temperature rise test.

		Temperature rise (K)	Limit (K)	Interpretation of test results
Temperature rise of the upper layer of oil		39.2	60	**Passed**
Middle temperature rise of the oil		32.1	--	--
Middle temperature rise of the winding	HV side	62.7	65	**Passed**
	LV side	48.3	65	**Passed**

Tab. 5: Temperature rise above ambient temperature, calculated by Standard ČSN EN 60076-2 ed.2. Uncertainty of temperature rise is maximally 1.2 K for oil measuring and 3.0 K for temperature rise test of winding. This uncertainty is calculated as product of standard uncertainty and coefficient "k", which corresponds to the interval of reliability circa 95%, which in case of standard distribution corresponds to coefficient k = 2.

Interpretation of the test results:

It is possible to certify according to the Standard ČSN EN 60076-2 ed.2, Clause. 7.11 „Uncertainties affecting the results of the temperature rise test", that the estimation of uncertainties should not be used for certification of specified limits gaining. Uncertainties should be used for information only.

Full wave lightning impulse test (LI)

Description

Full wave lightning impulse test was performed according to the Standard ČSN EN 60076-3 ed.2, Clause 13.2 at the principal tapping of the tested transformer with ratio 20/0.4 kV. The test was performed with standardized 1.2 μs $^{\pm 30\,\%}$/50 μs $^{\pm 20\,\%}$ lightning impulse of a negative polarity, **U** = 150 kV. The value of the testing voltage was chosen by the customer from the Standard ČSN EN 60076-3 ed.2, Table 2.

The test was performed for the following combination:

- 1 reference impulse (50 – 70% **U**),
- 3 impulses of 100 % **U** level.

This impulse combination was applied gradually to every phase terminal of the tested HV winding. The remaining phase terminals and the tank of the transformer were grounded. One additional measuring channel was used for the measurement of the current flowing from the remaining two interconnected phase terminal to the ground.

The lighting impulse test was performed under the following atmospheric conditions:

- atmospheric pressure: 100.2 kPa,
- temperature: 18.9 °C.

Results

The following test division and classification of each oscillogram is related to numeration, indicated under each following oscillogram **No. 1 – 13** in **figs 5-8:.**

Shape of wave – oscillogram 1.
Reference impulse – oscillograms 2 (phase 1U), 6 (phase 1V) and 10 (phase 1W).
Phase 1U – oscillograms 3, 4 and 5.
Phase 1V – oscillograms 7, 8 and 9.
Phase 1W – oscillograms 11, 12 and 13.

Interpretation of the test results:

It is evident (oscillograms in **fig. 5 - 8**) that the insulation of the tested transformer passed the lightning impulse tests (LI).

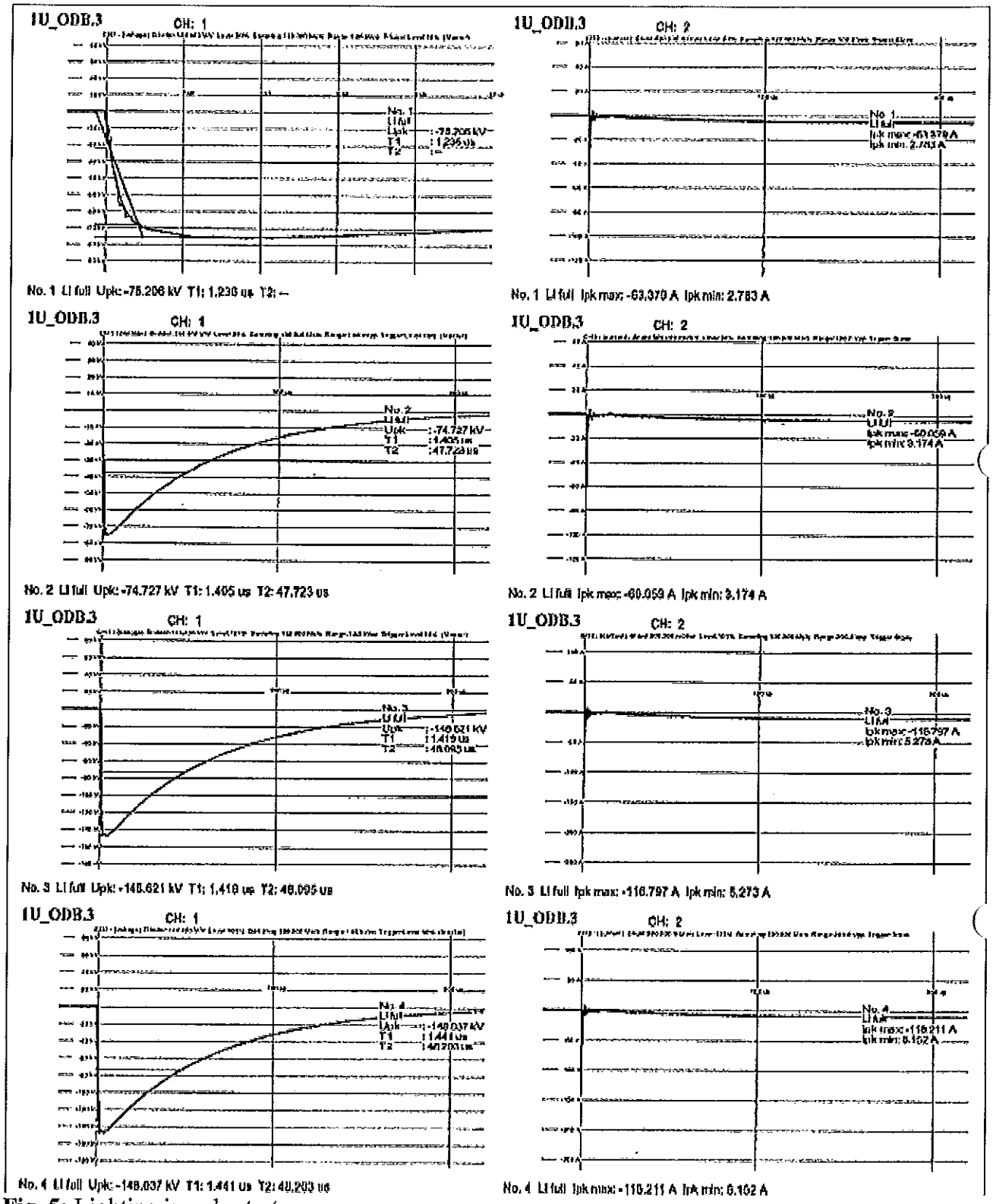


Fig. 5: Lighting impulse test.

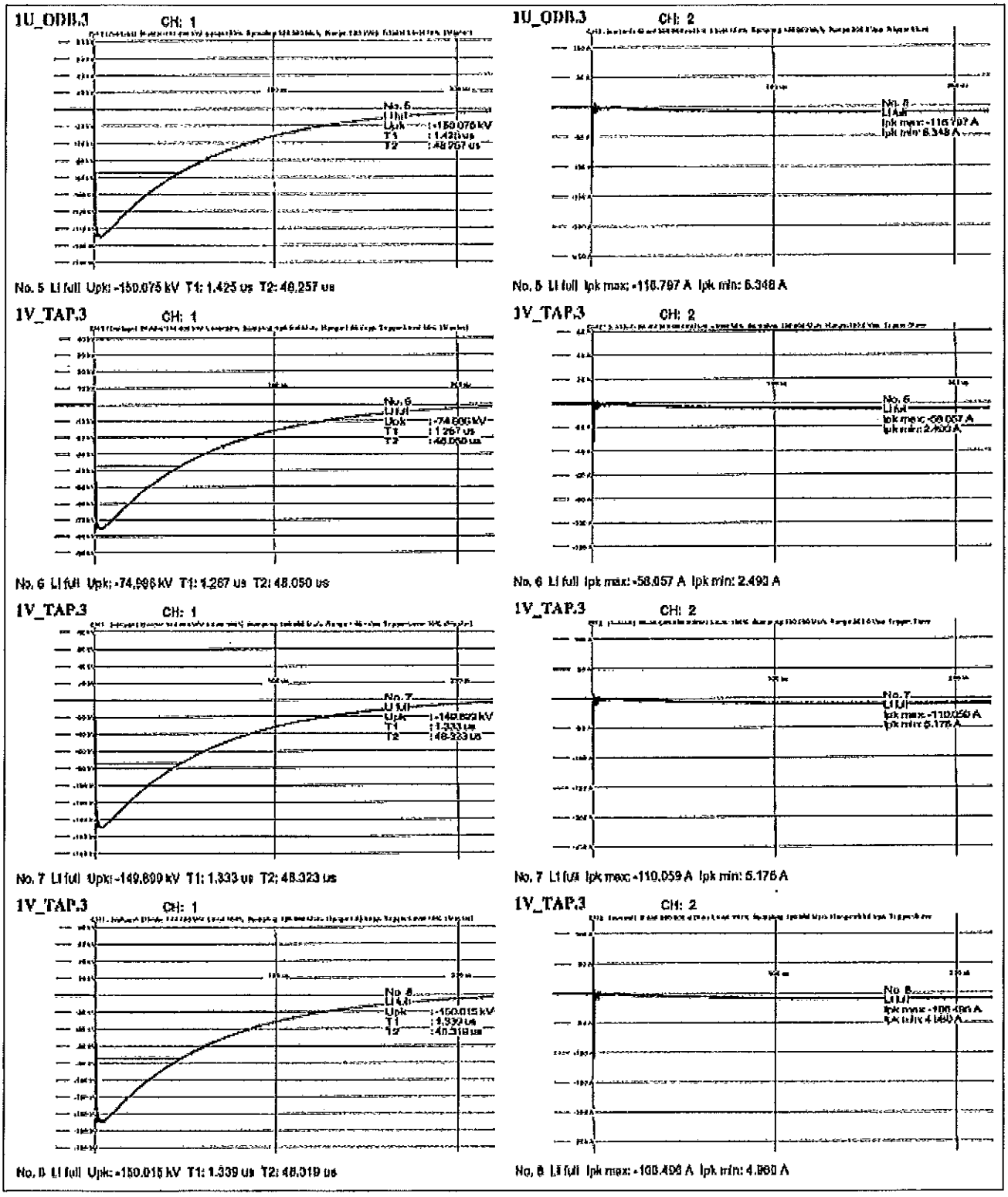


Fig. 6: Lighting impulse test.

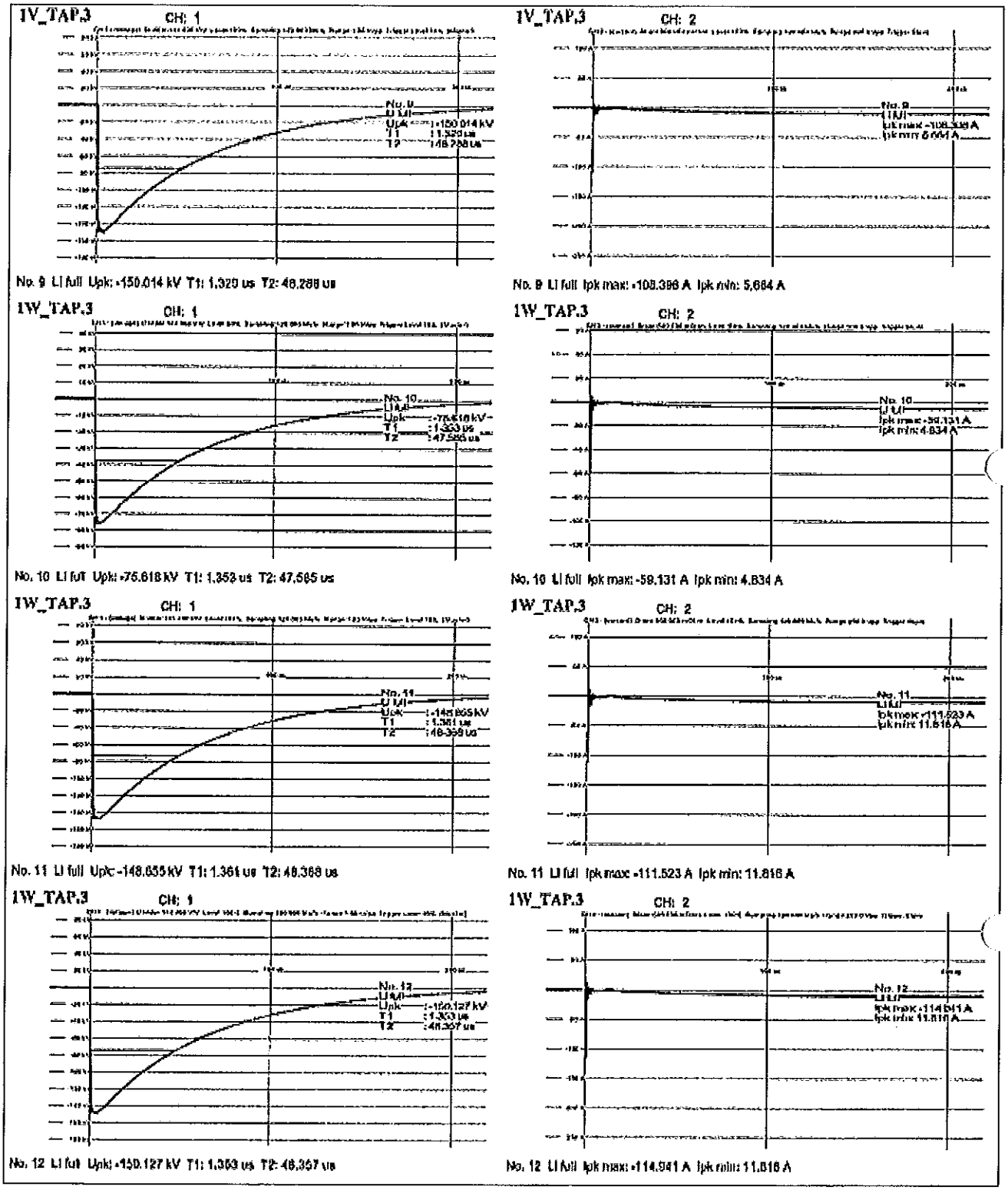


Fig. 7: Lighting impulse test.

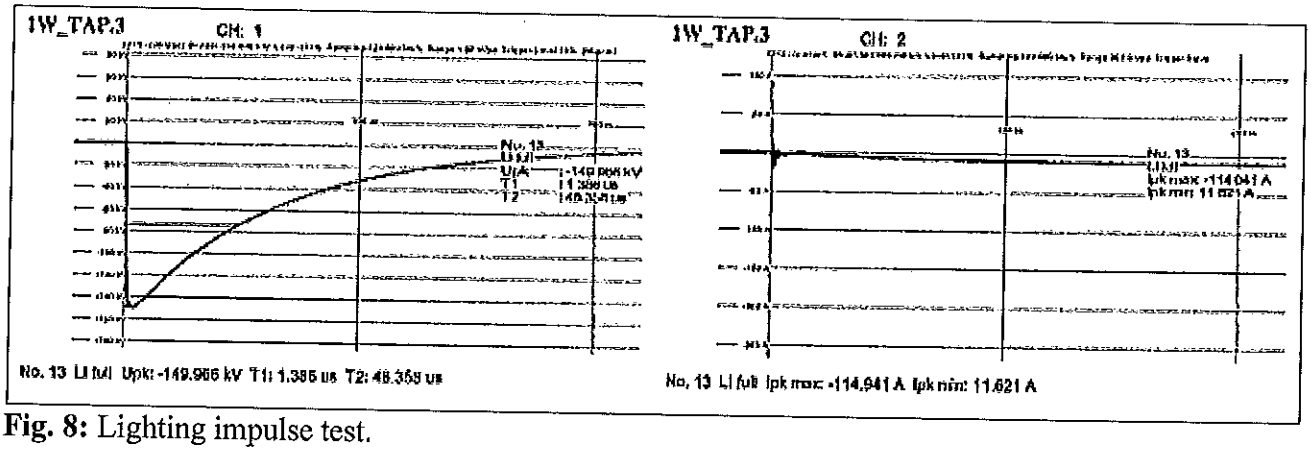


Fig. 8: Lighting impulse test.

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Olšanská 54/3, 130 00 Praha 3

issues

according to section 16 of Act No. 22/1997 Coll., on technical requirements for products, as amended

CERTIFICATE OF ACCREDITATION

No. 660 / 2015

ETD TRANSFORMÁTORY a.s.
with registered office Zborovská 54/22, 301 00 Plzeň, Company Registration No. 25137808

to the Testing Laboratory No. 1526
ELECTRICAL TESTING LABORATORY

Scope of accreditation:

Electrical and air-handling testing and measuring of industrial equipment to the extent as specified in the appendix to this Certificate.

This Certificate of Accreditation is a proof of Accreditation issued on the basis of assessment of fulfillment of the accreditation criteria in accordance with

ČSN EN ISO/IEC 17025:2005

In its activities performed within the scope and for the period of validity of this Certificate, the Body is entitled to refer to this Certificate, provided that the accreditation is not suspended and the Body meets the specified accreditation requirements in accordance with the relevant regulations applicable to the activity of an accredited Conformity Assessment Body.

This Certificate of Accreditation replaces, to the full extent, Certificate No.: 474/2014 of 15 July 2014, or any administrative acts building upon it.

The Certificate of Accreditation is valid until: 1 July 2018

Prague: 21 September 2015

Jiří Růžička
Director
Czech Accreditation Institute
Public Service Company

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L 1526

Total sheets: 5

Test Report

AP_EZ/2016/045/01/EN

Customer:	BEZ TRANSFORMÁTORY a.s. Rybničná 40 835 54 Bratislava		
Tested object:	**Transformer TOHn 378/10, s.n. 0361503**		
Test take over date:	September 23th , 2016		
Test realization date:	September 27th , 2016		
Test identification No.:	365-302-1624	**Evidentiary No:**	48/2016
Order No:	B06/4500006720		

Testing methods, regulations:

ACCREDITED TESTS ACCORDING TO SOP_EZ/2, 4, 6 and 8:

ČSN EN 60076-1, Clause 11.2	Measurement of winding resistance
ČSN EN 60076-1, Clause 11.4	Measurement of short-circuit impedance and load loss
ČSN EN 60076-1, Clause 11.5	Measurement of no-load loss and current

Test results: In the text.

Enclosures: --

AKREDITOVANÁ ELEKTROTECHNICKÁ ZKUŠEBNA L 1526 ETD TRANSFORMÁTORY a.s.

In Plzeň, 30th September 2016

Petr Šíma
Electrical Testing Laboratory Director

Test Report is issued in 3 copies – 2 are obtained by the customer and 1 is kept in the Laboratory.
Test Report is issued for the customer in electronic form too.

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Performed tests 1
Used apparatuses 1
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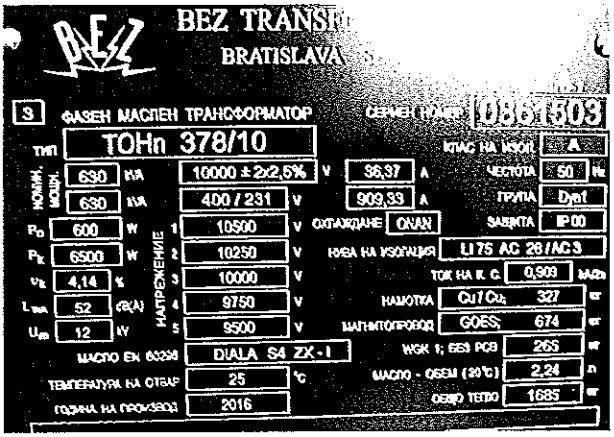
Description 2
Results 2
Measurement of short-circuit impedance and load loss 2
Description 2
Results 3
Measurement of no-load loss and currents 3
Description 3
Results 3

Tested object

Oil-immersed transformer TOHn 378/10.



Performed tests

Routine tests:

- Measurement of winding resistance according to the Standard ČSN EN 60076-1, Clause 11.2. The test was carried out at tappings 1, 3 and 5 of the tested transformer.
- Measurement of short-circuit impedance and load loss according to the Standard ČSN EN 60076-1, Clause 11.4. The test was carried out at tappings 1, 3 and 5 of the tested transformer.
- Measurement of no-load loss and current according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the tested transformer.

Used apparatuses

Name	Type	Filing No.
Digital multimeter	Fluke 189	PMMm 263
Digital multimeter	Fluke 179	PMMm 269
Isolating converters	BB3652	PMMp 254
Digital thermometer	GMH 3710	PMMt 268
Current transformer	ABB Petercem EA100	PMTr 92
Current transformer	ABB Petercem EA100	PMTr 93
Current transformer	ABB Petercem EA100	PMTr 94

Measurement of winding resistance

Description

The measurement of winding resistance was performed according to the Standard ČSN EN 60076-1, Clause 11.2.3. Measurement was carried out at tappings 1, 3 and 5 of the tested transformer in temperature steady state.

Winding resistances each of above mentioned tappings were measured with DC current, with Ohm's method, between terminals of each phase on HV side of transformer and between node and terminal of respective phase on LV side of tested transformer. The mean temperature of cooling liquid (temperature of transformer winding) was measured during the test. Temperature was 22.1 °C. Resulting value of the resistance was recalculated to 75 °C.

Results

Resistances of transformer winding are noted in **Tab. 1.**

Side of transformer	Tap	Terminal	Before type and special tests	
			$R_{measured}$ (Ω)	R_{75} (Ω)
HV	1 (+ 5 %)	1U – 1V	1.263367322	1.523906108
		1U – 1W	1.261630071	1.521810591
		1V – 1W	1.264324863	1.525061119
	3 (0 %)	1U – 1V	1.189650904	1.434987471
		1U – 1W	1.186356280	1.431013412
		1V – 1W	1.189263079	1.434519668
	5 (- 5 %)	1U – 1V	1.114140538	1.343904929
		1U – 1W	1.112359551	1.341756656
		1V – 1W	1.114562624	1.344414060
LV		2n – 2u	0.001058774	0.001276623
		2n – 2v	0.001091545	0.001316137
		2n – 2w	0.001083715	0.001306696

Tab. 1: Resistances of transformer winding.

Measurement of short-circuit impedance and load loss

Description

Measurement of short-circuit impedance and load loss was performed according to the Standard ČSN EN 60076-1, Clause 11.4. The test was carried out at tappings 1, 3 and 5 of the tested transformer in temperature steady state.

Voltage was applied to HV terminals of the transformer, LV terminals were short circuited. Supply current of 50 Hz was ca. 28 A. Temperature was 22.3 °C.

Measured values of short-circuit impedance and load loss were corrected for the reference temperature 75 °C.

Results

Measured values of short-circuit impedance and load loss are noted in **Tab. 2.**

	Z a ΔP_k		
Tapping	1 (+ 5 %)	3 (0 %)	5 (- 5 %)
$Z_{measured}$ (Ω)	7.29	6.52	5.73
Z_{75} (Ω)	7.33	6.57	5.79
$\Delta P_{k\ measured}$ (W)	4 468.19	5 381.09	6 461.08
$\Delta P_{k\ 75}$ (W)	5 427.18	6 308.32	7 356.14

Tab. 2: Values of the short-circuit impedance and load loss.

Measurement of no-load loss and currents

Description

Measurement of no-load losses and currents was performed according to the Standard ČSN EN 60076-1, Clause 11.5. The test was carried out at main tap of the tested transformer in temperature steady state.

Supply voltage was applied to LV terminals of the transformer; HV terminals were no-loaded. Supply voltage during the measurement was set to 90 %, 100 % and 110 % of rated voltage U_2.

Results

Measured values of no-load losses and currents are noted in **tab. 3** and **4.**

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
ΔP_0 (W)	444.2	591.4	799.9

Tab. 3: Values of the no-load losses.

	90 % U_2 (208 V)	100 % U_2 (231 V)	110 % U_2 (254 V)
I_0 (A)	1.3038	2.3427	7.1113

Tab. 4: Values of the no-load currents.

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Olšanská 54/3, 130 00 Praha 3

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