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TESTING
CNAS L1020



实验室名称: 国家电器产品质量监督检验中心

Lab Name: China National Center for Quality Supervision
and Test of Electrical Apparatus Products

No 21M0728-S

型式试验报告 Type Test Report

委托单位: China Electric Equipment (Jiangsu) Transformer
Manufacture Co., Ltd.

Client:

产品名称: Power transformer with on-load tap-changer

Name of Product:

产品型号: SSZ20-240000/220

Product Type:

检验类别: Commission test

Test Category:

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China National Center for Quality Supervision and Test of Electrical Apparatus Products Test Report

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Client	China Electric Equipment (Jiangsu) Transformer Manufacture Co., Ltd.	Test category	Commission test
Manufacturer	China Electric Equipment (Jiangsu) Transformer Manufacture Co., Ltd.	Date of sample receiving	Mar. 03, 2021
Name of sample	Power transformer with on-load tap-changer	Type of sample	SSZ20-240000/220
Address of manufacturer	No.188 Ganglong Road, Yangzhong, Zhenjiang, Jiangsu	Original number or date of production	ZD-202101011
Date of test	From Mar. 11, 2021 to Mar. 27, 2021	Number of sample	1 set
Test items	Routine test Type test (including calculation of the winding hot-spot temperature-rise) Measurement of bushing capacitances and dielectric dissipation factor ($\tan\delta$) Line terminal AC withstand test Measurement of frequency response Short-circuit withstand test Measurement of no-load excitation characteristics Long-duration no-load test Measurement of zero-sequence impedances on three-phase transformers Measurement of the harmonics of the no-load current Measurement of radio interference	Test standards	GB/T 1094.1—2013 GB/T 1094.2—2013 GB/T 1094.3—2017 GB/T 1094.5—2008 GB/T 1094.10—2003 GB/T 6451—2015 GB/T 7595—2017 GB 20052—2020 JB/T 10088—2016 IEC 60076-1:2011 IEC 60076-2:2011 IEC 60076-3:2013+AMD 1:2018 IEC 60076-5:2006 IEC 60076-10:2016 Commission requirements
Test conclusion	The test results of routine test, type test (including calculation of the winding hot-spot temperature-rise), measurement of bushing capacitances and dielectric dissipation factor ($\tan\delta$), line terminal AC withstand test, measurement of frequency response, short-circuit withstand test, measurement of no-load excitation characteristics, long-duration no-load test, measurement of zero-sequence impedances on three-phase transformers, measurement of the harmonics of the no-load current and measurement of radio interference of power transformer with on-load tap-changer (type: SSZ20-240000/220) are in accordance with test standards and commission requirements. The sample has passed the above tests. Signing and issuing date: 2021. 03. 30 Note: the conclusion is valid only for the inspected and tested sample		
Remarks	/		

Compiled by: 袁小勇

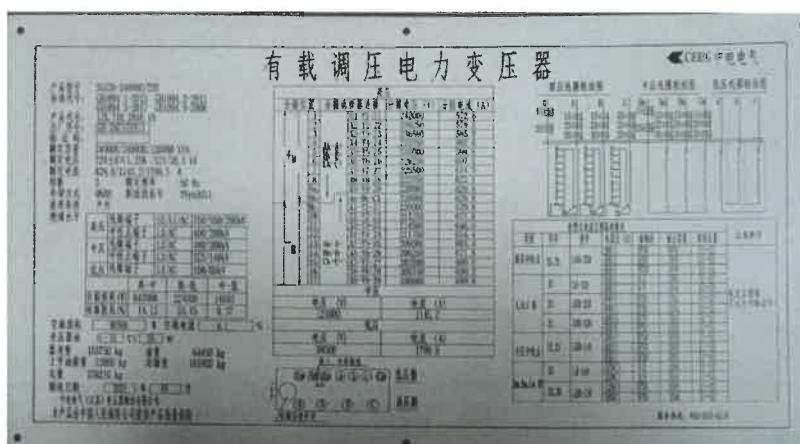
Proofread by: 张超

Checked by: 郭冬冬

Approved by: 李明智

Test Report	China National Center for Quality Supervision and Test of Electrical Apparatus Products	№: 21M0728-S Total 108 Page 02															
1. Sample parameters Rated power: 240000/240000/120000kVA Rated voltage: 220/121/38.5kV Rated current: 629.9/1145.2/1799.6A Rated frequency: 50Hz Number of phases: 3 Tapping ranges: $(220 \pm 8 \times 1.25\%) / 121 / 38.5\text{kV}$ Connection symbol: YNyn0d11 Cooling method: ONAN Class of insulation and heat-resistant: A <table border="0"> <tr> <td>Insulation level: HV</td> <td>$U_m / \text{SI/LI/LIC/AC}$</td> <td>252/750/950/1050/395kV</td> </tr> <tr> <td>HVN</td> <td>$U_m / \text{LI/AC}$</td> <td>126/400/200kV</td> </tr> <tr> <td>MV</td> <td>$U_m / \text{LI/LIC/AC}$</td> <td>126/480/530/200kV</td> </tr> <tr> <td>MVN</td> <td>$U_m / \text{LI/AC}$</td> <td>72.5/325/140kV</td> </tr> <tr> <td>LV</td> <td>$U_m / \text{LI/LIC/AC}$</td> <td>40.5/200/220/85kV</td> </tr> </table> 2. Test standards GB/T 1094.1—2013 <i>Power transformers—Part 1: General</i> GB/T 1094.2—2013 <i>Power transformers—Part 2: Temperature rise for liquid-immersed transformers</i> GB/T 1094.3—2017 <i>Power transformers—Part 3: Insulation levels, dielectric tests and external clearances in air</i> GB/T 1094.5—2008 <i>Power transformers—Part 5: Ability to withstand short circuit</i> GB/T 1094.10—2003 <i>Power transformers—Part 10: Determination of sound levels</i> GB/T 6451—2015 <i>Technical parameters and requirements of oil-immersed power transformer</i> GB/T 7595—2017 <i>Quality of transformer oils in service</i> GB 20052—2020 <i>Minimum allowable values of energy efficiency and the energy efficiency grades for power transformers</i> JB/T 10088—2016 <i>Sound level for 6kV~1000kV power transformers</i> IEC 60076-1:2011 <i>Power transformers – Part 1: General</i> IEC 60076-2:2011 <i>Power transformers – Part 2: Temperature rise for liquid – immersed transformers</i> IEC 60076-3:2013+AMD1:2018 <i>Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air</i> IEC 60076-5:2006 <i>Power transformers – Part 5: Ability to withstand short circuit</i> IEC 60076-10:2016 <i>Power transformers – Part 10: Determination of sound levels</i> Commission requirements 3. Sample description The power transformer with on-load tap-changer is for outdoor use and the structure of the coil is rotundate concentric type coil. The loss parameters of the sample meets the requirements of grade two energy efficiency of GB20052—2020 and external photos of the sample have been attached.			Insulation level: HV	$U_m / \text{SI/LI/LIC/AC}$	252/750/950/1050/395kV	HVN	$U_m / \text{LI/AC}$	126/400/200kV	MV	$U_m / \text{LI/LIC/AC}$	126/480/530/200kV	MVN	$U_m / \text{LI/AC}$	72.5/325/140kV	LV	$U_m / \text{LI/LIC/AC}$	40.5/200/220/85kV
Insulation level: HV	$U_m / \text{SI/LI/LIC/AC}$	252/750/950/1050/395kV															
HVN	$U_m / \text{LI/AC}$	126/400/200kV															
MV	$U_m / \text{LI/LIC/AC}$	126/480/530/200kV															
MVN	$U_m / \text{LI/AC}$	72.5/325/140kV															
LV	$U_m / \text{LI/LIC/AC}$	40.5/200/220/85kV															

Photos of the sample



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Summary of test results					
No	Test items	Specified value	Measured value		Conc- clusion
		Standards (commission requirements)	Before short-circuit test	After short-circuit test	
1	Measurement of d.c. insulation resistance windings-to-earth and between windings (routine test)	Providing value of insulation resistance Providing absorption ratio Providing polarity index	See 4.1	See 4.21.4.1	/
2	Check of core and frame insulation for liquid-immersed transformers with core or frame insulation (routine test)	Providing value of insulation resistance 20℃(GΩ): ≥0.5	See 4.2	See 4.21.4.2	PASS
3	Measurement of dissipation factor (tanδ) of the insulation system capacitances (routine test)	Providing value of capacitance Providing dielectric dissipation factor tanδ(20℃): ≤0.8%	See 4.3	See 4.21.4.3	PASS
4	Determination of capacitances windings-to-earth and between windings (routine test)	Providing value of capacitance	See 4.4	See 4.21.4.4	/
5	Measurement of bushing capacitances and dielectric dissipation factor (tanδ) (commission test)	Providing value of capacitance Providing dielectric dissipation factor tanδ	See 4.5	See 4.21.4.5	/
6	Check the ratio and polarity of built-in current transformers (routine test)	Providing the value of ratio and polarity relation	See 4.6	See 4.21.4.6	/
7	Insulation test of auxiliary wiring (AuxW)(routine test)	Secondary windings of current transformer: 2.5kV 60s on-load tap-changer: 2.0kV 60s	2.5kV 60s 2.0kV 60s	2.5kV 60s 2.0kV 60s	PASS
8	Measurement of voltage ratio and check of phase displacement (routine test)	Voltage ratio tolerance of principal tapping: obtaining the lower of the following values between ±0.5% of declared ratio and ±1/10 of the actual percentage impedance Connection symbol: YNyn0d11	See 4.8	See 4.21.4.8	PASS
9	Measurement of winding resistance (routine test)	Maximum resistance unbalance rate Phase resistance: ≤2% Line resistance: ≤1%	HV (phase): 0.42% MV (phase): 0.18% LV (line): 0.41%	HV (phase): 0.38% MV (phase): 0.13% LV (line): 0.57%	PASS

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No	Test items	Specified value		Measured value				Conc- clusion
		Standards (commission requirements)		Before short-circuit test		After short-circuit test		
10	Measurement of no-load loss and current (routine test)	I ₀ (%): 0.35 P ₀ (kW): 100.000	+30% +0%	0.10 96.126		0.10 96.148		PASS
11	Measurement of no-load loss and current at 90% and 110% of rated voltage (routine test)	I ₀ (%): P ₀ (kW):	measured measured	90% 0.05	110% 0.52	90% 0.05	110% 0.52	/
				73.810	121.491	73.828	121.695	
12	Measurement of short-circuit impedance and load loss (routine test)	t: 75℃ Z(%): HV—LV: 24.0 HV—MV: 14.0 MV—LV: 8.0 HV—MV: P _k (kW): 667.000 P _{total} (kW): 767.000	 ±10% ±7.5% ±10% +0% +0%	24.49 14.13 8.38 647.384 743.510		24.49 14.14 8.36 647.421 743.569		PASS
13	Tests on on-load tap-changers (routine test)	According to clause 11.7 of GB/T1094.1-2013 and IEC60076-1:2011		Meet the requirements		Meet the requirements		PASS

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No	Test items	Specified value		Measured value				Conc- clusion
		Standards (commission requirements)		Before short-circuit test		After short-circuit test		
14	Lightning impulse test (LI, LIC, LIN) (routine test, type test)	HV :		/		947.12~963.55		PASS
		Full wave (kV): 950	±3%			1031.13~1060.11		
		Chopped wave (kV): 1050	±3%			397.49~401.37		
		Neutral point (kV): 400		±3%				
		MV :		/		479.92~484.93		
		Full wave (kV): 480	±3%			525.63~530.96		
		Chopped wave (kV): 530	±3%			321.34~325.91		
		Neutral point (kV): 325		±3%				
		LV:		/		197.30~204.20		
Full wave (kV): 200	±3%	218.28~221.19						
Chopped wave (kV): 220		±3%						
15	Switching impulse test (SI) (routine test)	Switching wave (kV): 750 ±3%		744.70~763.39		744.24~766.91		PASS
16	Separate-source AC withstand voltage test (AV) (routine test)	HV neutral point: 200kV 60s		200.0kV	60s	200.0kV	60s	PASS
		MV neutral point: 140kV 60s		140.0kV	60s	140.0kV	60s	
		LV: 85kV 60s		85.0kV	60s	85.0kV	60s	
17	Line terminal AC withstand test (LTAC) (special test)	Phase to earth test						PASS
		Test voltage (kV): 73.5		73.5		73.5		
		Induced voltage (kV): 395(HV)/200(MV)		395/200		395/200		
		Duration (min): 120(f _n /f)		0.5		0.5		
		Frequency (Hz): >50		200		200		

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No	Test items	Specified value	Measured value		Concl- usion
		Standards (commission requirements)	Before short-circuit test	After short-circuit test	
18	Induced AC withstand voltage test with partial discharge measurement (IVPD) (routine test)	Three-phase applied voltage			PASS
		0.4U _r /√3 (kV) Discharge magnitude≤50pC	50.8 A:<5;B:<5;C:<5 Am:<10;Bm:<10; Cm:<10	50.8 A:<10;B:<10;C:<10 Am:<10;Bm:<10; Cm:<10	
		1.2U _r /√3 (kV) Duration (min): 1	152.4 1 A:<30;B:<30;C:<30 Am:<40;Bm:<40; Cm:<40	152.4 1 A:<35;B:<35;C:<35 Am:<30;Bm:<30; Cm:<30	
		1.58U _r /√3 (kV) Duration (min): 5	200.7 5 A:<60;B:<60;C:<60 Am:<70;Bm:<70; Cm:<70	200.7 5 A:<60;B:<70;C:<70 Am:<60;Bm:<60; Cm:<60	
		1.8U _r /√3 (kV) Duration (min): 0.5	228.6 0.5	228.6 0.5	
		1.58U _r /√3 (kV) Duration (min): 60 Discharge magnitude≤250pC	200.7 60 A:<60;B:<60;C:<70 Am:<70;Bm:<70; Cm:<80	200.7 60 A:<70;B:<70;C:<70 Am:<60;Bm:<60; Cm:<60	
		1.2U _r /√3 (kV) Duration (min): 5 Discharge magnitude≤100pC	152.4 1 A:<30;B:<30;C:<40 Am:<40;Bm:<40; Cm:<50	152.4 1 A:<30;B:<30;C:<30 Am:<30;Bm:<30; Cm:<30	
		0.4U _r /√3 (kV) Discharge magnitude≤50pC	50.8 A:<5;B:<5;C:<10 Am:<10;Bm:<10; Cm:<15	50.8 A:<10;B:<10;C:<10 Am:<10;Bm:<10; Cm:<10	
		Frequency (Hz): >50	200		

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No	Test items	Specified value	Measured value		Concl- usion
		Standards (commission requirements)	Before short-circuit test	After short-circuit test	
19	Insulating liquid test, measurement of dissolved gasses in dielectric liquid from each separate oil compartment except diverter switch compartment (routine test)	Breakdown voltage (kV): ≥ 45 $\tan\delta$ (90°C): $\leq 0.5\%$ Water content (mg/L): ≤ 15	66.4 0.05% 5.6	62.1 0.05% 6.1	PASS
		Providing gas chromatograph analysis: Hydrogen: $<10\mu\text{L/L}$ Acetylene: 0 Total hydrocarbon: $<20\mu\text{L/L}$	See 4.19	See 4.21.4.19	
20	Measurement of frequency response (special test)	Providing frequency response characteristics curve	See 4.20	See 4.21.4.20	/
21	Short-circuit withstand test (special test)	Test times of each phase: 3 times Duration (s): $0.25\pm 10\%$ The test oscillogram shall be normal. The reactance tolerance of phase before and after the test is not more than 1% The appearance and out-of-tank inspection does not reveal any obvious defects. Routine retests shall be passed after short-circuit test.	3 times HV-LV: 0.254~0.255 HV-MV: 0.258~0.260 Without abnormality The maximum reactance tolerance of phase HV-LV: 0.27% HV-MV: 0.41% Without obvious defects. Routine retests are passed.		PASS
22	Measurement of no-load excitation characteristics (commission test)	Providing no-load excitation characteristic curve	See 4.22		/
23	Long-duration no-load test (special test)	Applied voltage (kV): $1.1U_r$ Duration (h): 12 Oil without acetylene	$1.1U_r$ 12 For gas analysis, see 4.21.4.19		PASS
24	Measurement of zero-sequence impedances on three-phase transformers (special test)	Providing zero-sequence impedances values (Ω)	See 4.24		/
25	Measurement of the harmonics of the no-load current (commission test)	Providing harmonics of the no-load current of each phase	Harmonics of the no-load current of I_1-I_{19}		/
26	Measurement of radio interference (commission test)	Providing radio interference voltage level (μV)	See 4.26		/

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No	Test items	Specified value	Measured value	Conc- lusion	
		Standards (commission requirements)			
27	Temperature-rise test (including calculation of the winding hot-spot temperature-rise) (type test)	Top oil temperature-rise limits (K): 53 Winding temperature-rise limits (K): 60 Winding hot-spot temperature-rise limits (K): 78 Temperature-rise limits of tank surface and structural parts (K): 75	Top oil temperature-rise: 47.5 HV winding temperature-rise: 53.3 MV winding temperature-rise: 54.2 LV winding temperature-rise: 56.3 HV winding temperature-rise: 72.5 MV winding temperature-rise: 73.6 LV winding temperature-rise: 76.1 Temperature-rise of tank surface and structural parts: 61.0	PASS	
28	Leak testing with pressure for liquid-immersed transformers (routine test)	Body: Applied pressure (kPa): 30 Duration (h): 24 No oil leakage or damage	30.0 24 No oil leakage or damage	PASS	
		On-load tap-changer tank: Applied pressure (kPa): 30 Duration (h): 24 No oil leakage or damage	30.0 24 No oil leakage or damage		
29	Determination of sound levels (type test)	Sound pressure level $\overline{L}_{PA}$ dB(A): ≤ 65 Sound power level L_{WA} dB(A): ≤ 96	62 85	PASS	
30	Mechanical strength test of tank (type test)	Applied degree of vacuum (kPa): 0.133 Applied positive pressure (kPa): 100 Elastic deformation of tank wall (mm): ≤ 25 Elastic deformation of tank cover (mm): ≤ 30 Permanent deformation of tank wall (mm): ≤ 12 Permanent deformation of tank cover (mm): ≤ 10 No damage	See 4.30	PASS	
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4. Test items and results					
4.1 Measurement of d.c. insulation resistance windings-to-earth and between windings (routine test)					
Test date: Mar. 11, 2021 Relative humidity: 41%; Oil temperature: 14.2°C					
Measured parts	R ₁₅ (GΩ)	R ₆₀ (GΩ)	R ₆₀₀ (GΩ)	Absorption ratio (R ₆₀ /R ₁₅)	Polarity index (R ₆₀₀ /R ₆₀)
HV—MV, LV and earth	4.25	5.66	8.90	1.33	1.57
MV—HV, LV and earth	4.56	6.18	9.30	1.36	1.50
LV—HV, MV and earth	5.51	7.21	11.3	1.31	1.57
HV, MV, LV—earth	5.62	7.32	11.6	1.30	1.58
HV, MV—LV and earth	5.48	7.20	10.8	1.31	1.50
HV—LV	5.25	6.89	10.7	1.31	1.55
MV—LV	4.72	6.15	9.28	1.30	1.51
HV—MV	4.45	5.81	8.93	1.31	1.54
4.2 Check of core and frame insulation for liquid-immersed transformers with core or frame insulation (routine test)					
Test date: Mar. 11, 2021 Relative humidity: 41%; Oil temperature: 14.2°C					
Measured parts	Measured insulation resistance (GΩ)		Insulation resistance corrected to 20°C(GΩ)		
Core—earth	2.82		2.23		
Frame—earth	2.94		2.32		
Core—frame	3.91		3.09		
4.3 Measurement of dissipation factor (tanδ) of the insulation system capacitances (routine test)					
Test date: Mar. 11, 2021 Relative humidity: 41%; Oil temperature: 14.2°C					
Measured parts	Dielectric dissipation factor corrected to 20°C tanδ (%)		Capacitance (pF)		
HV—MV, LV and earth	0.33		16410		
MV—HV, LV and earth	0.31		30460		
LV—HV, MV and earth	0.29		37620		
HV, MV, LV—earth	0.29		29250		
HV, MV—LV and earth	0.33		26680		
HV—LV	0.28		9280		
MV—LV	0.27		17520		
HV—MV	0.29		10180		
4.4 Determination of capacitances windings-to-earth and between windings (routine test)					
Test date: Mar. 11, 2021					
See 4.3.					

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4.5 Measurement of bushing capacitances and dielectric dissipation factor (tanδ) (commission test)						
Test date: Mar. 11, 2021 Relative humidity: 41 %; Oil temperature: 14.2℃						
Measured contents	Applied voltage	Measured parts				
		A	B	C	O	
		202004007	202004006	202004005	202004110	
tanδ(%)	10kV	0.31	0.31	0.32	0.32	
Measured capacitance (pF)		358.2	357.9	357.9	285.6	
Measured contents	Applied voltage	Measured parts				
		Am	Bm	Cm	Om	
		202004091	202004093	202004092	202011030	
tanδ(%)	10kV	0.29	0.28	0.28	0.31	
Measured capacitance (pF)		312.5	310.2	311.4	386.1	

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4.6 Check the ratio and polarity of built-in current transformers (routine test)				Test date: Mar. 11, 2021
Installation positions	Terminals	Ratio	Polarity	
A	1S1-1S2	600.09	-	
	1S1-1S3	800.24	-	
	2S1-2S2	600.12	-	
	2S1-2S3	800.20	-	
	3S1-3S2	119.87	-	
	3S1-3S3	159.93	-	
B	1S1-1S2	600.12	-	
	1S1-1S3	799.85	-	
	2S1-2S2	599.95	-	
	2S1-2S3	800.12	-	
	3S1-3S2	120.05	-	
	3S1-3S3	160.18	-	
C	1S1-1S2	599.85	-	
	1S1-1S3	800.12	-	
	2S1-2S2	600.35	-	
	2S1-2S3	800.05	-	
	3S1-3S2	120.08	-	
	3S1-3S3	160.27	-	
O	1S1-1S2	199.87	-	
	1S1-1S3	400.11	-	
	1S1-1S4	600.27	-	
	2S1-2S2	200.25	-	
	2S1-2S3	399.92	-	
	2S1-2S4	600.14	-	
Om	1S1-1S2	200.32	-	
	1S1-1S3	400.11	-	
	1S1-1S4	599.83	-	
	2S1-2S2	200.05	-	
	2S1-2S3	400.32	-	
	2S1-2S4	600.19	-	

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Installation positions	Terminals	Ratio	Polarity		
Am	1S1-1S2	1250.6	-		
	1S1-1S3	2501.1	-		
	2S1-2S2	1249.2	-		
	2S1-2S3	2500.7	-		
	3S1-3S2	1250.2	-		
	3S1-3S3	2500.2	-		
Bm	1S1-1S2	1250.4	-		
	1S1-1S3	2501.2	-		
	2S1-2S2	1250.2	-		
	2S1-2S3	2500.2	-		
	3S1-3S2	1250.3	-		
	3S1-3S3	2500.1	-		
Cm	1S1-1S2	1249.8	-		
	1S1-1S3	2500.1	-		
	2S1-2S2	1250.1	-		
	2S1-2S3	2500.4	-		
	3S1-3S2	1250.4	-		
	3S1-3S3	2500.3	-		
4.7 Insulation test of auxiliary wiring (AuxW) (routine test) Relative humidity: 41%; Ambient temperature: 13.7℃; Oil temperature: 14.2℃; Air pressure: 102kPa					
Test date: Mar. 11, 2021					
Parts of applied voltage		Test voltage (kV)	Test duration (s)	Result	
Wiring for current transformer secondary windings	A	2.5	60	PASS	
	B				
	C				
	O				
	Am				
	Bm				
	Cm				
	Om				
Wiring for auxiliary power and control circuit	Power for on-load tap-changer	2.0	60		

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4.8 Measurement of voltage ratio and check of phase displacement (routine test)								Test date: Mar. 11, 2021
HV winding		LV winding		Transformer ratio by calculation	Measured voltage ratio tolerance (%)			Connection symbol
Tapping position	Voltage (kV)	Tapping position	Voltage (kV)		AB/ab	BC/bc	CA/ca	
1	242.00	/	38.5	6.286	0.04	0.05	0.05	YNd11
2	239.25			6.214	0.06	0.08	0.09	
3	236.50			6.143	0.03	0.07	0.07	
4	233.75			6.071	0.03	0.06	0.08	
5	231.00			6.000	0.07	0.08	0.08	
6	228.25			5.929	0.01	0.01	0.02	
7	225.50			5.857	0.02	0.02	0.03	
8	222.75			5.786	0.01	0.01	0.03	
9b	220.00			5.714	0.03	0.05	0.05	
10	217.25			5.643	0.00	0.02	0.02	
11	214.50			5.571	-0.03	-0.01	-0.01	
12	211.75			5.500	0.04	0.05	0.05	
13	209.00			5.429	0.01	0.01	0.01	
14	206.25			5.357	-0.06	-0.06	-0.04	
15	203.50			5.286	-0.03	-0.03	-0.03	
16	200.75			5.214	0.03	0.03	0.03	
17	198.00			5.143	0.02	0.02	0.04	
MV winding		LV winding		Transformer ratio by calculation	Measured voltage ratio tolerance (%)			Connection symbol
Tapping position	Voltage (kV)	Tapping position	Voltage (kV)		AmBm/ab	BmCm/bc	CmAm/ca	
/	121	/	38.5	3.143	0.06	0.06	0.10	ynd11

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HV winding		MV winding		Transforme r ratio by calculation	Measured voltage ratio tolerance (%)			Connection symbol
Tapping position	Voltage (kV)	Tapping position	Voltage (kV)		AB/AmBm	BC/BmCm	CA/CmAm	
1	242.00	/	121	2.000	0.10	0.05	0.05	YNyn0
2	239.25			1.977	-0.07	-0.07	-0.01	
3	236.50			1.954	0.02	0.02	0.02	
4	233.75			1.932	-0.04	-0.04	0.01	
5	231.00			1.909	0.00	0.00	0.00	
6	228.25			1.886	0.03	0.03	0.03	
7	225.50			1.864	-0.03	-0.03	-0.03	
8	222.75			1.841	-0.05	0.00	0.00	
9b	220.00			1.818	0.05	0.05	0.05	
10	217.25			1.795	0.03	0.03	0.03	
11	214.50			1.773	-0.04	-0.04	-0.04	
12	211.75			1.750	0.00	0.00	0.00	
13	209.00			1.727	-0.02	-0.02	-0.02	
14	206.25			1.704	-0.03	0.03	0.03	
15	203.50			1.681	0.01	0.01	0.01	
16	200.75			1.659	-0.01	-0.01	-0.01	
17	198.00			1.636	0.04	0.04	0.04	

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4.9 Measurement of winding resistance (routine test)					Test date: Mar. 11, 2021 Oil temperature: 14.2℃
Winding	Tapping position	Measured values (Ω)			Resistance unbalance rate (%)
		A~O Am~Om a~b	B~O Bm~Om b~c	C~O Cm~Om c~a	
HV	1	0.1944	0.1942	0.1938	0.31
	2	0.1912	0.1910	0.1905	0.37
	3	0.1885	0.1883	0.1879	0.32
	4	0.1852	0.1850	0.1847	0.27
	5	0.1826	0.1824	0.1819	0.38
	6	0.1793	0.1791	0.1787	0.34
	7	0.1766	0.1764	0.1760	0.34
	8	0.1734	0.1732	0.1728	0.35
	9b	0.1697	0.1697	0.1696	0.06
	10	0.1739	0.1737	0.1733	0.35
	11	0.1765	0.1764	0.1760	0.28
	12	0.1798	0.1797	0.1792	0.33
	13	0.1825	0.1824	0.1819	0.33
	14	0.1857	0.1856	0.1852	0.27
	15	0.1885	0.1883	0.1878	0.37
	16	0.1918	0.1916	0.1910	0.42
	17	0.1944	0.1942	0.1937	0.36
MV	/	39.11×10 ⁻³	39.18×10 ⁻³	39.15×10 ⁻³	0.18
LV	/	12.29×10 ⁻³	12.33×10 ⁻³	12.28×10 ⁻³	0.41

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4.10 Measurement of no-load loss and current (routine test)						Test date: Mar. 12, 2021		
Voltage multiple	Applied voltage (kV)		No-load current		No-load loss (kW)			
	Average value	r.m.s. value	(A)	(%)	Measured value	Corrected value		
90%Ur	34.641	34.667	1.72	0.05	73.866	73.810		
100%Ur	38.510	38.523	3.55	0.10	96.158	96.126		
110%Ur	42.347	42.353	18.87	0.52	121.508	121.491		
Remarks: at 100%Ur, the difference between r.m.s. voltage and average voltage is within 3%.								
4.11 Measurement of no-load loss and current at 90% and 110% of rated voltage (routine test) See 4.10.								
4.12 Measurement of short-circuit impedance and load loss (routine test)						Test date: Mar. 12, 2021 Oil temperature: 13.3℃		
Winding	Tapping position	Applied current I		Measured voltage (kV)	Short-circuit impedance (for each phase)		Load loss (kW)	Total loss (kW)
		(A)	I/Ir (%)		HV impedance (Ω)	(%)	Corrected value	Corrected value
					t=75℃ I=Ir	t=75℃ I=Ir	t=75℃ I=Ir	t=75℃ I=Ir
HV LV	1	152.76	53.36	16.333	61.73	25.30	212.357	308.483
	9b	170.15	54.03	14.553	49.39	24.49	224.440	320.566
	17	191.08	54.61	12.541	37.90	23.20	238.974	335.100
HV MV	1	343.60	60.01	21.721	36.50	14.96	562.755	658.881
	9b	350.06	55.58	17.270	28.49	14.13	647.384	743.510
	17	390.36	55.78	15.343	22.70	13.89	759.400	855.526
MV LV	/	311.06	54.32	2.753	5.11	8.38	144.666	240.792

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4.13 Tests on on-load tap-changers (routine test) Test date: Mar. 12, 2021

Operation tests:

- with the transformer de-energized, eight complete cycles of operation (a cycle of operation goes from one end of the tapping range to the other, and back again);
- with the transformer de-energized, and with the auxiliary voltage reduced to 85 % of its rated value, one complete cycle of operation;
- with the transformer energized at rated voltage and frequency at no load, one complete cycle of operation;
- with one winding short-circuited and, as far as practicable, rated current in the tapped winding, 10 cycles of tap-change operations across the range of two steps on each side from where a coarse or reversing changeover selector operates, or otherwise from the middle tapping (the tapchanger will pass 20 times through the changeover position).

Test result: PASS

4.14 Lightning impulse test (LI, LIC, LIN) (routine test)
The test is not applied before the short-circuit withstand test.

4.15 Switching impulse test (SI) (routine test) Test date: Mar. 13, 2021

Atmospheric conditions of test:
Relative humidity: 50%; Ambient temperature: 13.2℃; Oil temperature: 13.9℃; Air pressure: 102kPa.

Test items and voltage		
Withstand terminals	Rated withstand voltage (kV)	Tapping position
A, B, C	750	1

Test sequence:

Line terminal

One reduced voltage switching impulse test;

Three rated voltage switching impulse test;

Test records:

T1: wave front time; Td: peak value; Tz: duration of over zero; Upk: peak voltage .

For waveform diagram, see P₁₉~P₂₁.

Voltage ranges of oscillograms are as below:

Withstand terminals	Switching wave
A, B, C	744.70~763.39

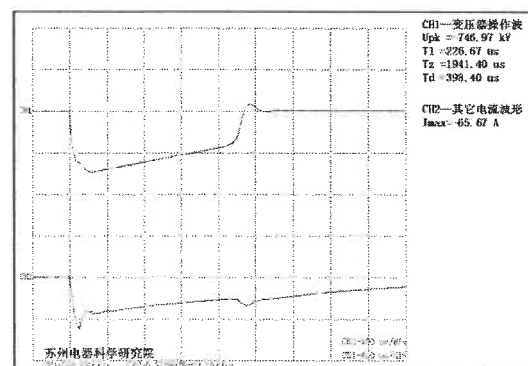
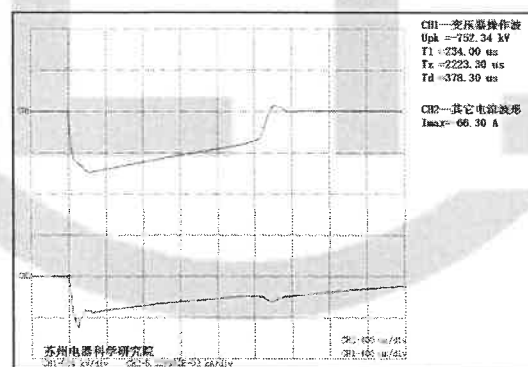
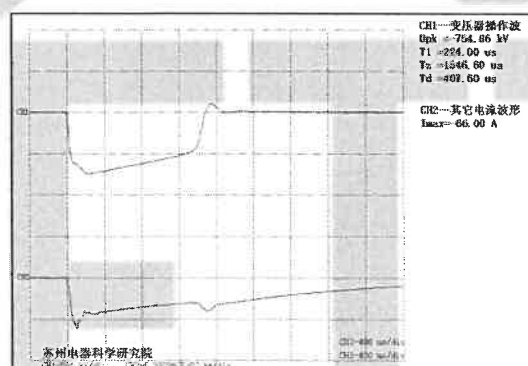
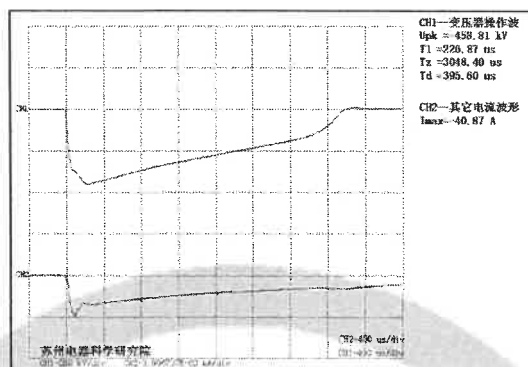
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Tested terminal: A Test polarity: negative Channel 1: voltage wave Channel 2: current wave



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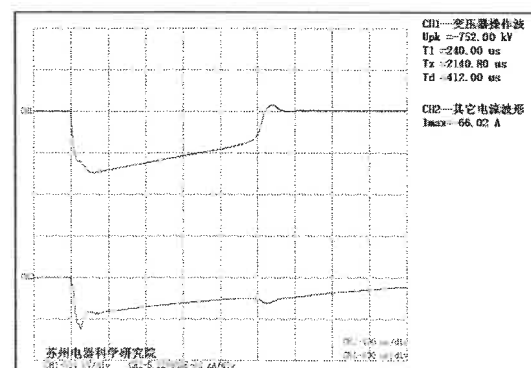
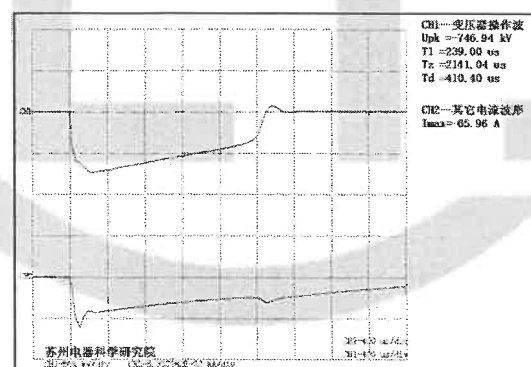
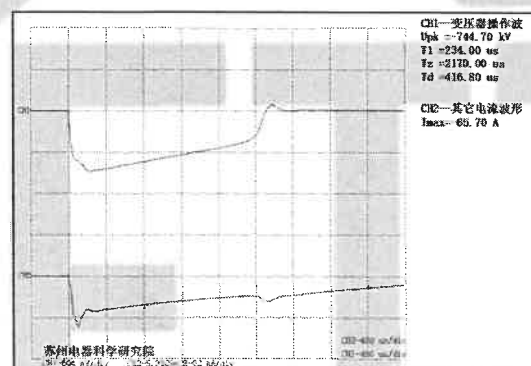
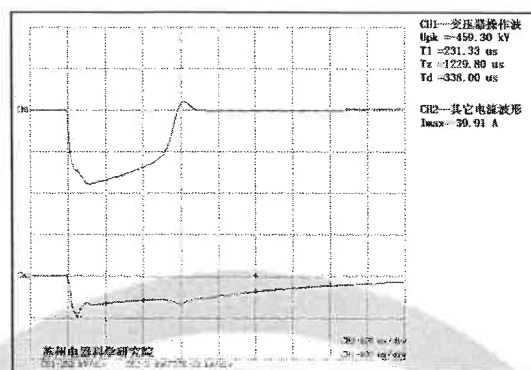
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Tested terminal: B

Test polarity: negative

Channel 1: voltage wave

Channel 2: current wave



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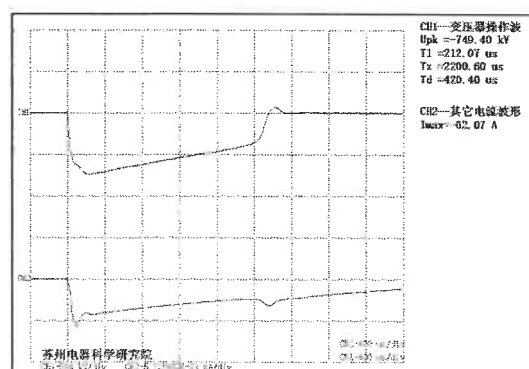
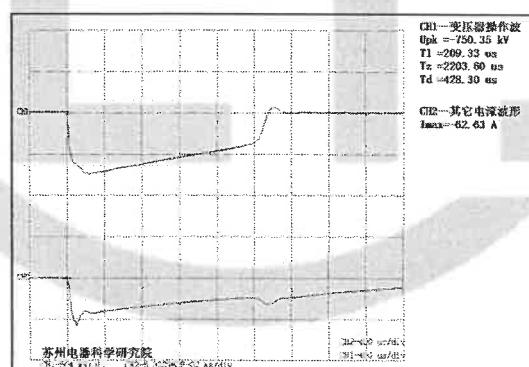
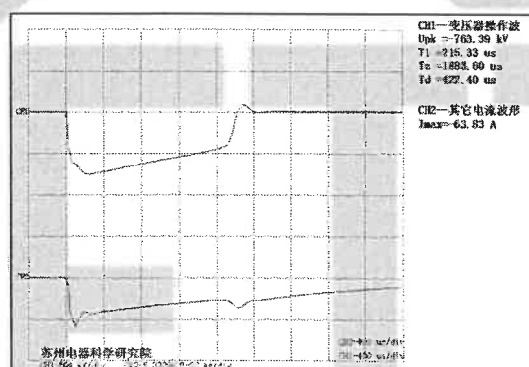
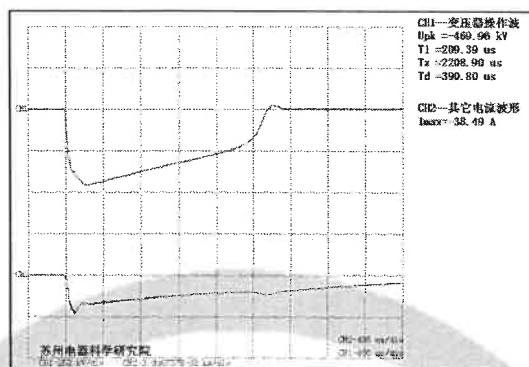
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Tested terminal: C

Test polarity: negative

Channel 1: voltage wave

Channel 2: current wave



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4.16 Separate-source AC withstand voltage test (AV) (routine test)							Test date: Mar. 13, 2021		
Relative humidity: 57%; Ambient temperature: 13.5℃; Oil temperature: 14.1℃; Air pressure: 102kPa									
Parts of applied voltage			Test voltage (kV)			Test duration (s)		Result	
HV neutral point—MV, LV and earth			220			60		PASS	
MV neutral point—HV, LV and earth			140			60			
LV—HV, MV and earth			85			60			
4.17 Line terminal AC withstand test (LTAC) (special test)							Test date: Mar. 14, 2021		
Relative humidity: 50%; Ambient temperature: 14.1℃; Oil temperature: 14.7℃; Air pressure: 101kPa									
Phase to earth test									
Parts of applied voltage	Tapping position	Applied voltage (kV)	Induced voltage (kV)				Frequency (Hz)	Test duration (s)	Result
		LV	HV		MV				
a-c	2	73.5	A	395.0	Am	200.0	200	30	PASS
a-b		73.5	B	395.0	Bm	200.0			
b-c		73.5	C	395.0	Cm	200.0			

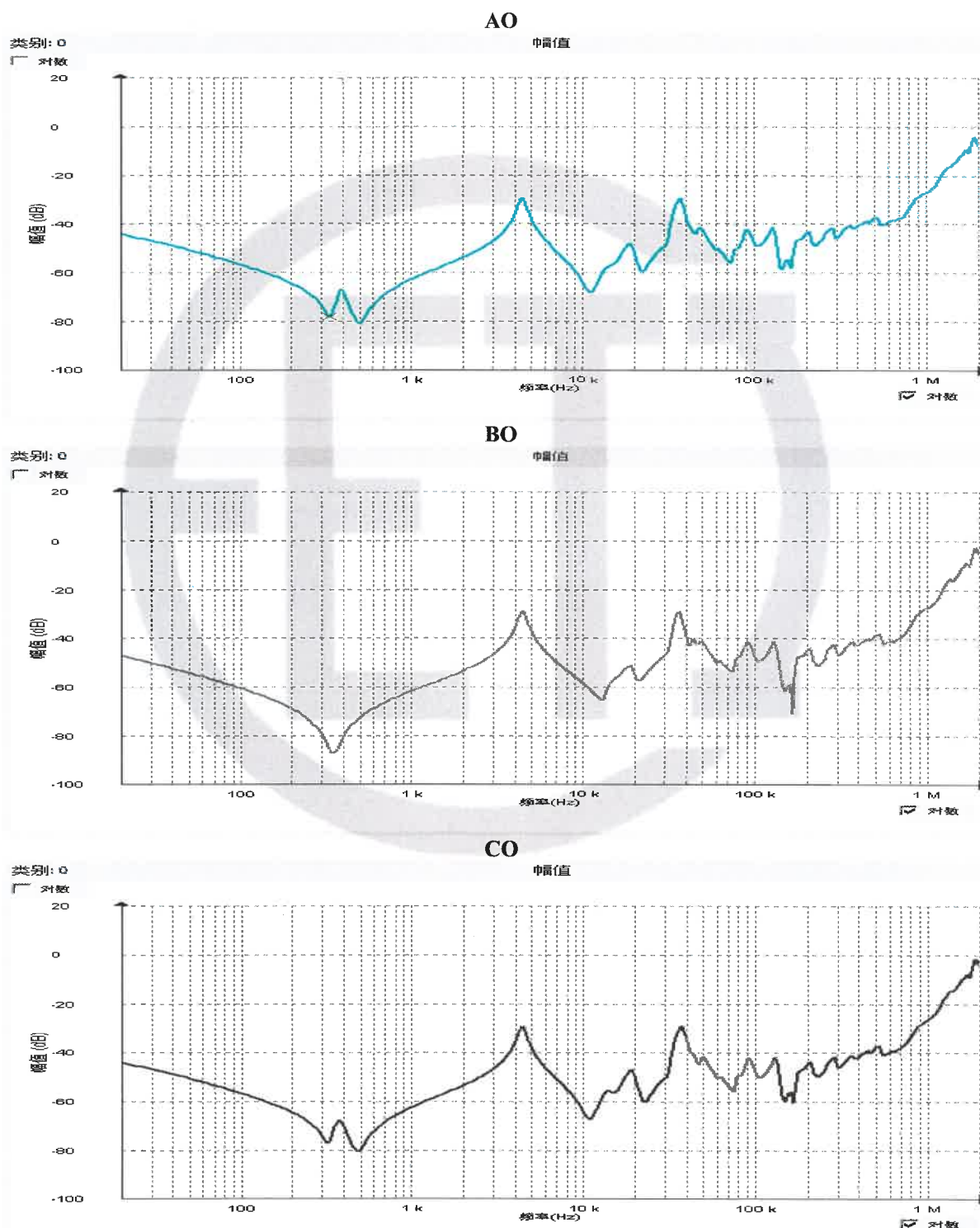
Test Report		China National Center for Quality Supervision and Test of Electrical Apparatus Products				№: 21M0728-S Total 108 Page 23		
4.18 Induced AC withstand voltage test with partial discharge measurement (IVPD) (routine test)								
Test date: Mar. 14, 2021								
Relative humidity: 50%; Ambient temperature: 14.1℃; Oil temperature: 14.7℃; Air pressure: 101kPa								
HV tapping position is 9b, frequency is 200Hz.								
Applied voltage		Duration (min)	Partial discharge magnitude (pC)					
Multiple	Phase to phase voltage (kV)		A	B	C	Am	Bm	Cm
$0.4U_r/\sqrt{3}$	50.8	/	<5	<5	<5	<10	<10	<10
$1.2U_r/\sqrt{3}$	152.4	1	<30	<30	<30	<40	<40	<40
$1.58U_r/\sqrt{3}$	200.7	5	<60	<60	<60	<70	<70	<70
$1.8U_r/\sqrt{3}$	228.6	0.5	/	/	/	/	/	/
$1.58U_r/\sqrt{3}$	200.7	5	<60	<60	<70	<70	<70	<80
		10	<60	<60	<60	<70	<70	<70
		15	<60	<60	<60	<60	<70	<70
		20	<60	<60	<60	<60	<70	<70
		25	<60	<60	<60	<60	<70	<70
		30	<60	<60	<60	<60	<70	<70
		35	<60	<60	<60	<60	<60	<60
		40	<60	<60	<60	<60	<70	<70
		45	<60	<60	<60	<60	<70	<70
		50	<60	<60	<60	<60	<70	<70
		55	<60	<60	<60	<60	<70	<70
		60	<60	<60	<60	<60	<70	<70
$1.2U_r/\sqrt{3}$	152.4	1	<30	<30	<40	<40	<40	<50
$0.4U_r/\sqrt{3}$	50.8	/	<5	<5	<10	<10	<10	<15
Remarks: Ur=220kV.								

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4.19 Insulating liquid test, measurement of dissolved gasses in dielectric liquid from each separate oil compartment except diverter switch compartment (routine test)							
Test date: Mar. 11, 2021 Relative humidity: 60%; Ambient temperature: 18.0°C							
Dielectric dissipation factor(90°C)	Breakdown voltage (kV)			Water content (mg/L)			
0.05%	66.4			5.6			
Gas chromatograph analysis (before all tests)						Test date: Mar. 11, 2021 μL/L	
H ₂	CO	CO ₂	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₂ H ₂	Total hydrocarbon
0	14.72	95.61	0.11	0	0	0	0.11
Gas chromatograph analysis (after dielectric tests, before short-circuit test)						Test date: Mar. 14, 2021 μ L/L	
H ₂	CO	CO ₂	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₂ H ₂	Total hydrocarbon
0	15.63	102.60	0.13	0	0	0	0.13

4.20 Measurement of frequency response (special test)

Test date: Mar. 19, 2021

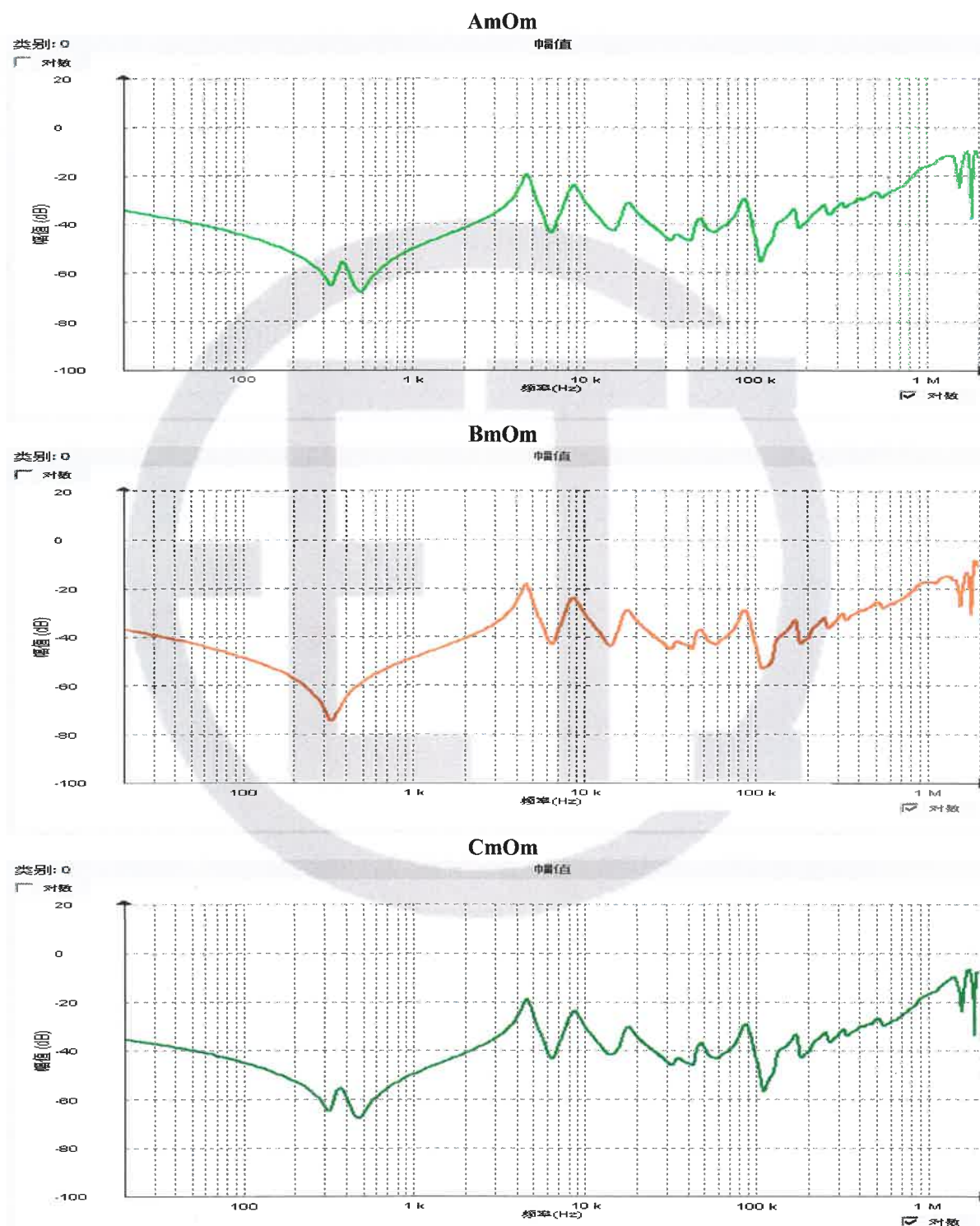
The test is carried out at the rated tap of high voltage
HV winding frequency response curves before short-circuit test



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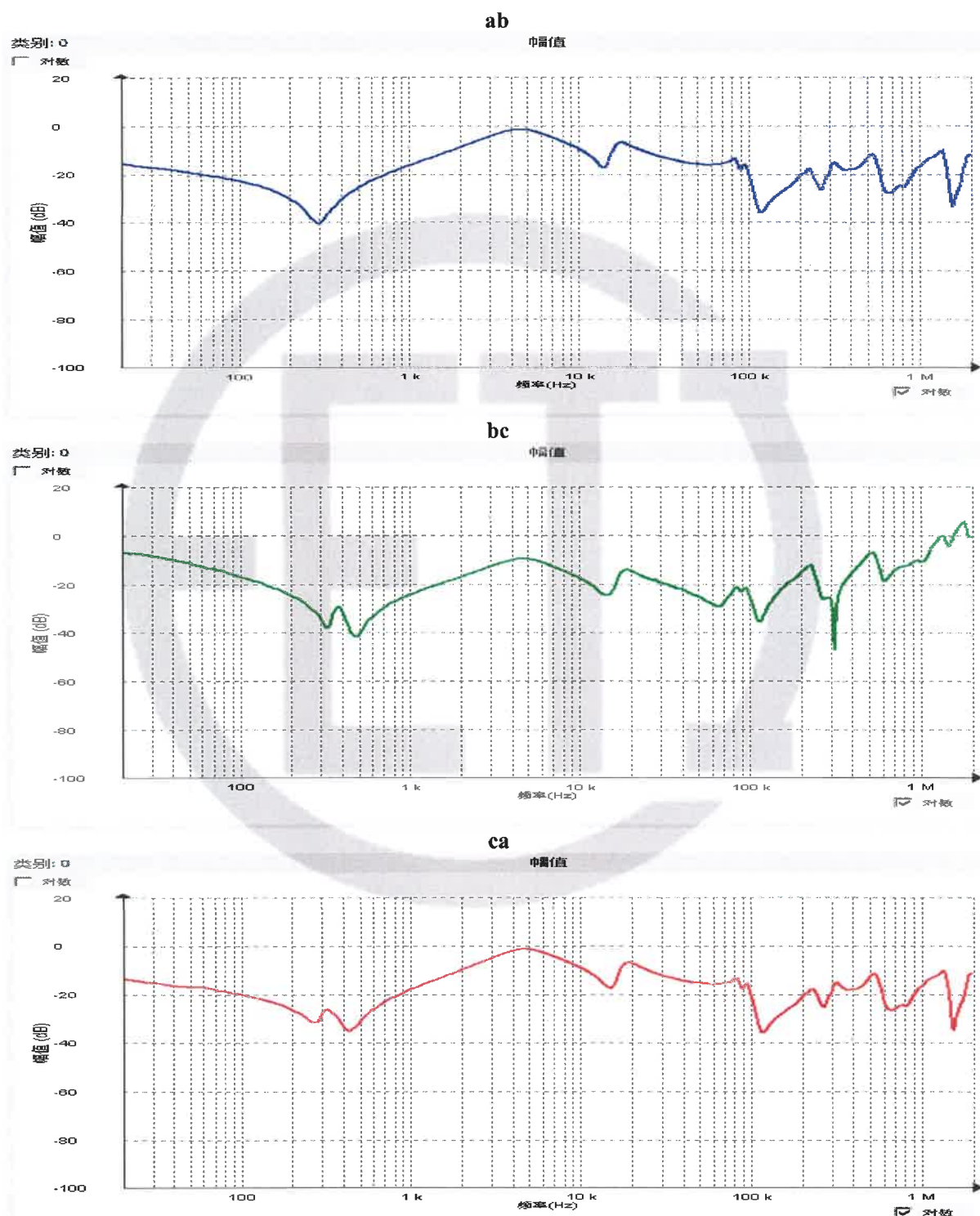
MV winding frequency response curves before short-circuit



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LV winding frequency response curves before short-circuit



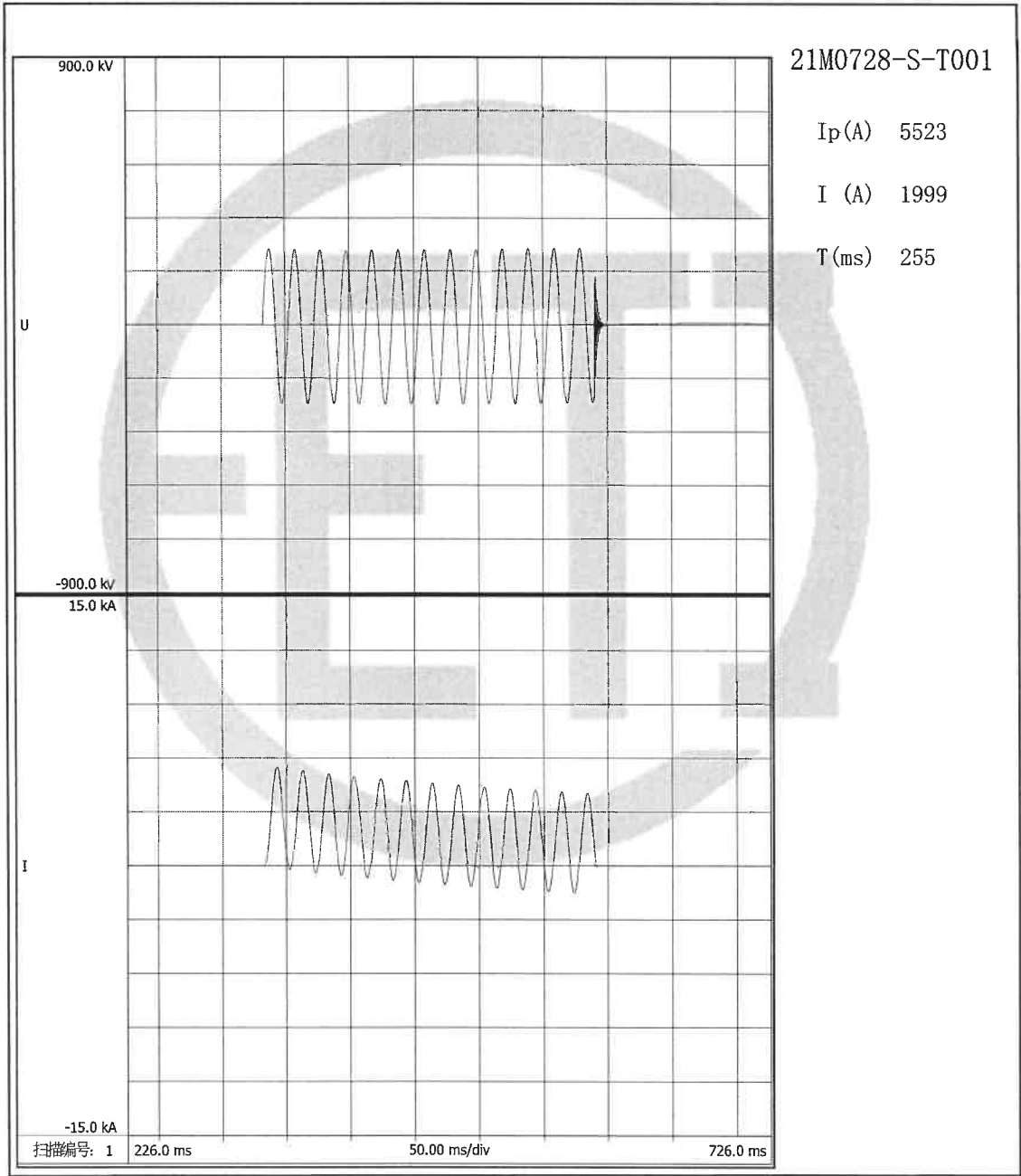
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4.21 Short-circuit withstand test (special test)								
4.21.1 HV -LV short-circuit test				Test date: Mar. 19, 2021				
Single-phase supply should be used, HV neutral point is earthed, and test voltage shall be supplied between one HV line terminal and the neutral point line terminal connected together. LV is connected by short-circuit and earthed, MV is open-circuit and MV neutral point is earthed. The test oscillogram shall be normal. For the test oscillogram, see P _{31~39} .								
4.21.1.1 Current calculation of short-circuit test (reference temperature 75℃)								
Tapping position		Symmetrical current value of phase (A)		Peak current value of phase (A)		Peak coefficient ($K\sqrt{2}$)		
1		2082		5601		2.69		
9b		2319		6238		2.69		
17		2642		7107		2.69		
4.21.1.2 Current injection of short-circuit test								
Tapping position /phase category	Applied voltage terminal	Times	Measurement of current					
			Symmetrical current value of phase		Peak current value of phase		Duration (s)	Oscillogram No
			Measured values (A)	(%)	Measured values (A)	(%)		
1/A	A-O	The first test	1999	96.01	5523	98.61	0.255	21M0728-S-T001
		The second test	2051	98.51	5633	100.57	0.255	21M0728-S-T002
		The third test	1995	95.82	5479	97.82	0.254	21M0728-S-T003
		Times	Measurement of reactance					
			Reactance values of phase (Ω)			Reactance variation of phase (%)		
			A			A		
		Before tests	61.704			/		
		The first test	61.704			0.00		
		The second test	61.735			0.05		
		The third test	61.739			0.06		
The maximum reactance variation of phase is 0.06%.								

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Tapping position /phase category	Applied voltage terminal	Times	Measurement of current					
			Symmetrical current value of phase		Peak current value of phase		Duration (s)	Oscillogram No
			Measured values (A)	(%)	Measured values (A)	(%)		
9b/B	B-O	The first test	2267	97.76	6239	100.02	0.254	21M0728-S-T004
		The second test	2229	96.12	6205	99.47	0.254	21M0728-S-T005
		The third test	2222	95.82	6149	98.57	0.254	21M0728-S-T006
		Times	Measurement of reactance					
			Reactance values of phase (Ω)				Reactance variation of phase (%)	
			B				B	
		Before tests	49.332				/	
		The first test	49.398				0.13	
		The second test	49.405				0.15	
		The third test	49.405				0.15	
The maximum reactance variation of phase is 0.15%.								

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Tapping position /phase category	Applied voltage terminal	Times	Measurement of current					
			Symmetrical current value of phase		Peak current value of phase		Duration (s)	Oscillogram No
			Measured values (A)	(%)	Measured values (A)	(%)		
17/C	C-O	The first test	2566	97.12	7098	98.87	0.255	21M0728-S-T007
		The second test	2599	98.37	7176	100.97	0.255	21M0728-S-T008
		The third test	2610	98.79	7179	101.01	0.255	21M0728-S-T009
		Times	Measurement of reactance					
			Reactance values of phase (Ω)				Reactance variation of phase (%)	
			C				C	
		Before tests	37.809				/	
		The first test	37.866				0.15	
		The second test	37.897				0.23	
		The third test	37.910				0.27	
		The maximum reactance variation of phase is 0.27%.						

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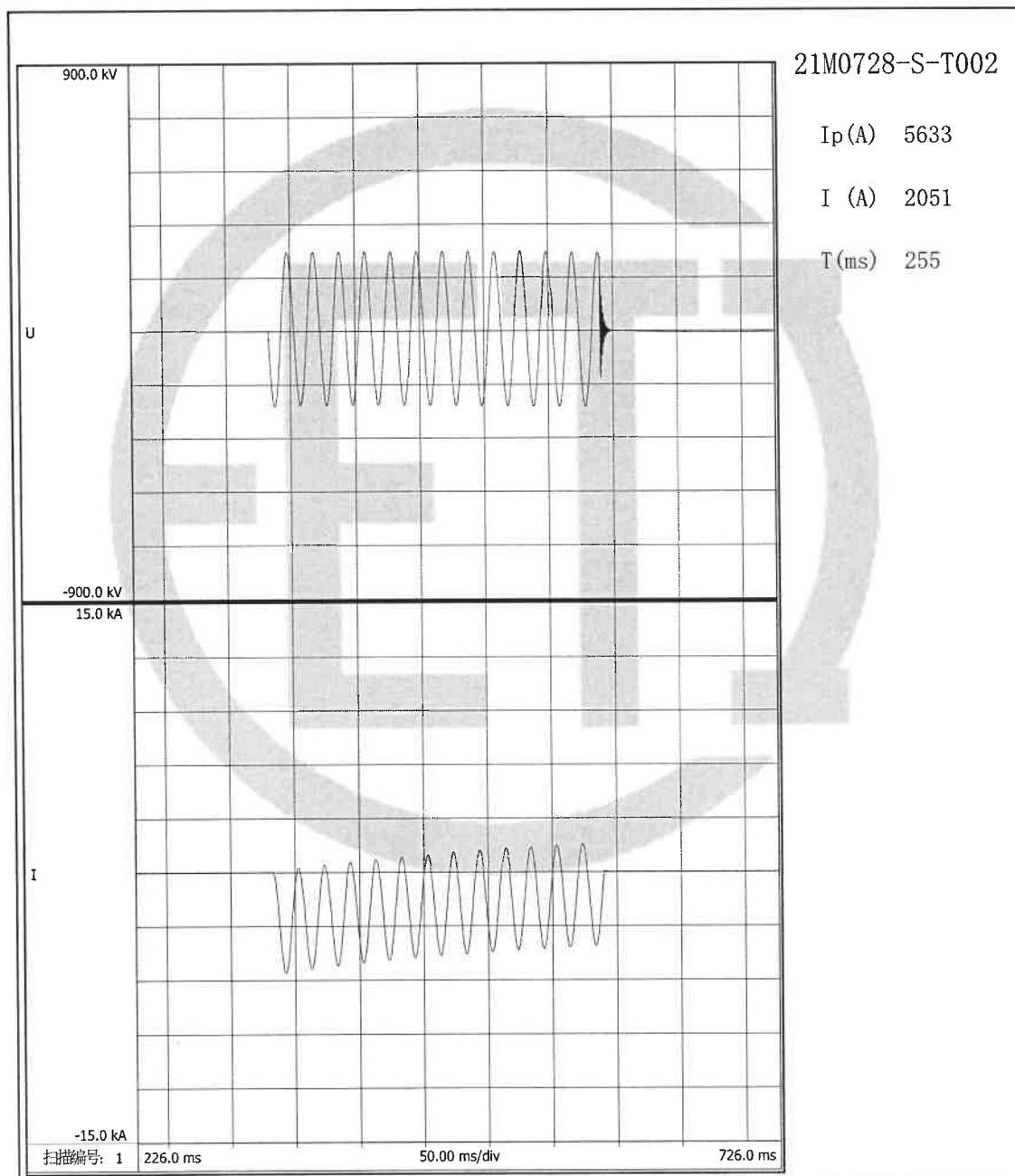
Oscillogram



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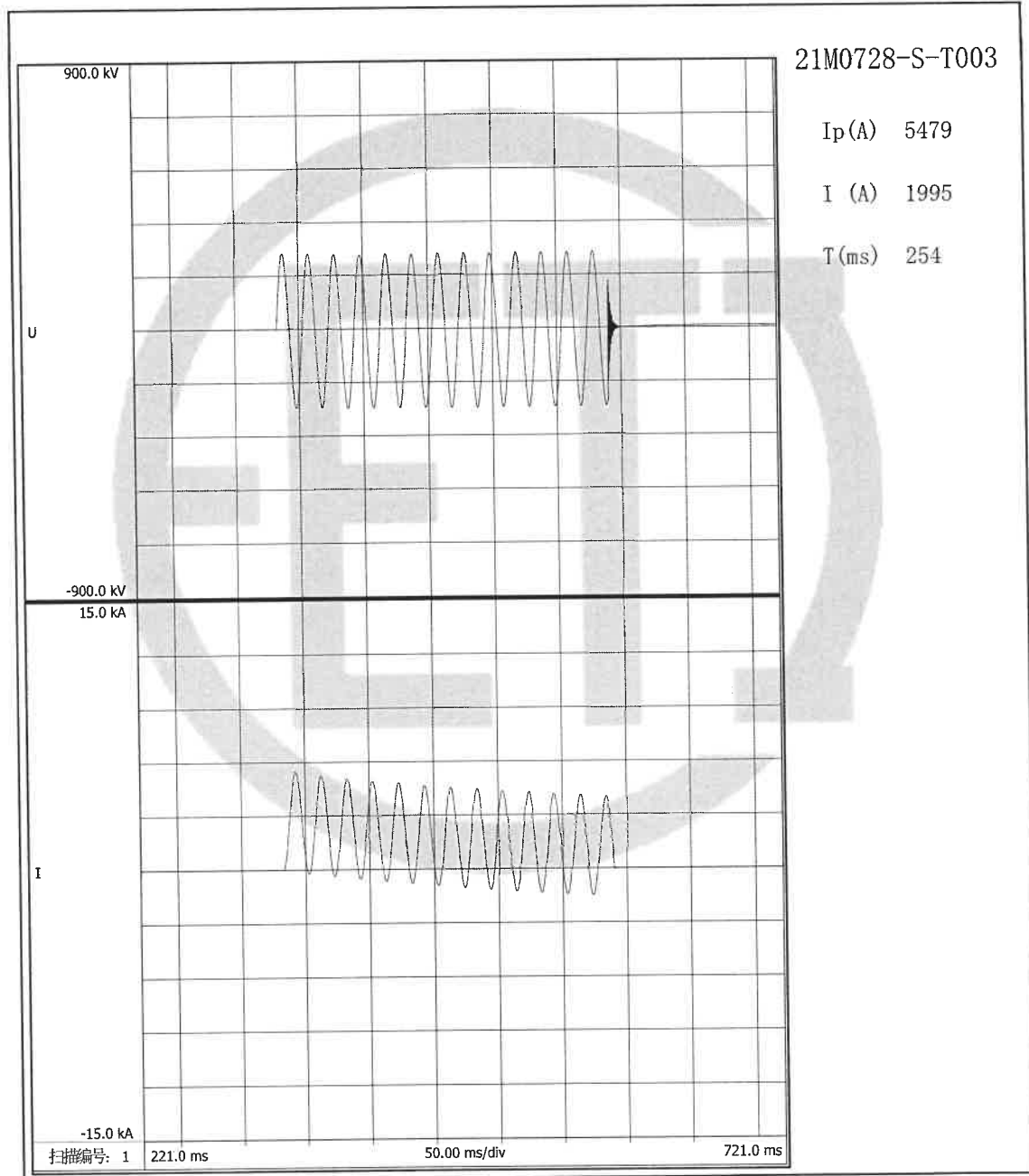
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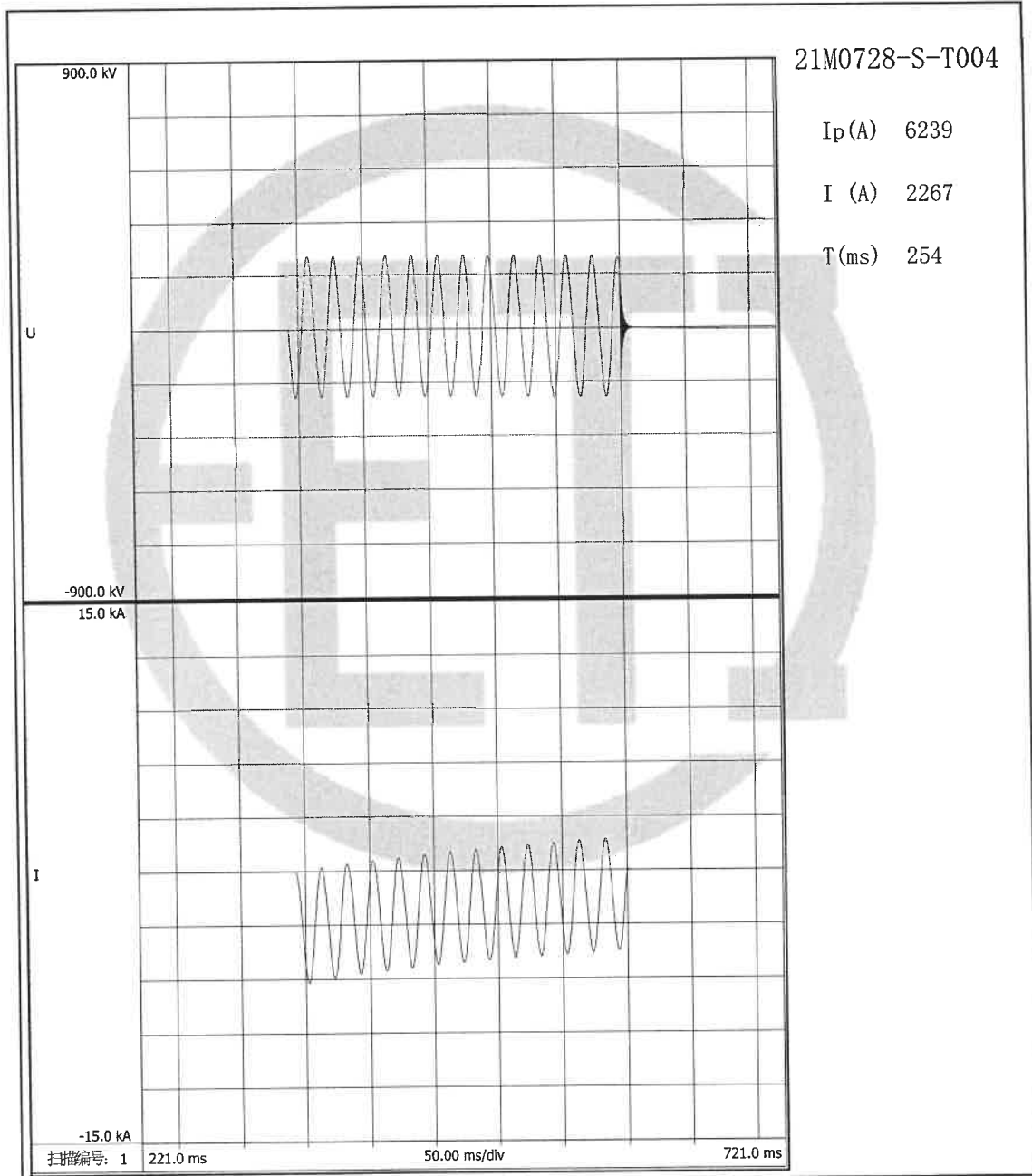
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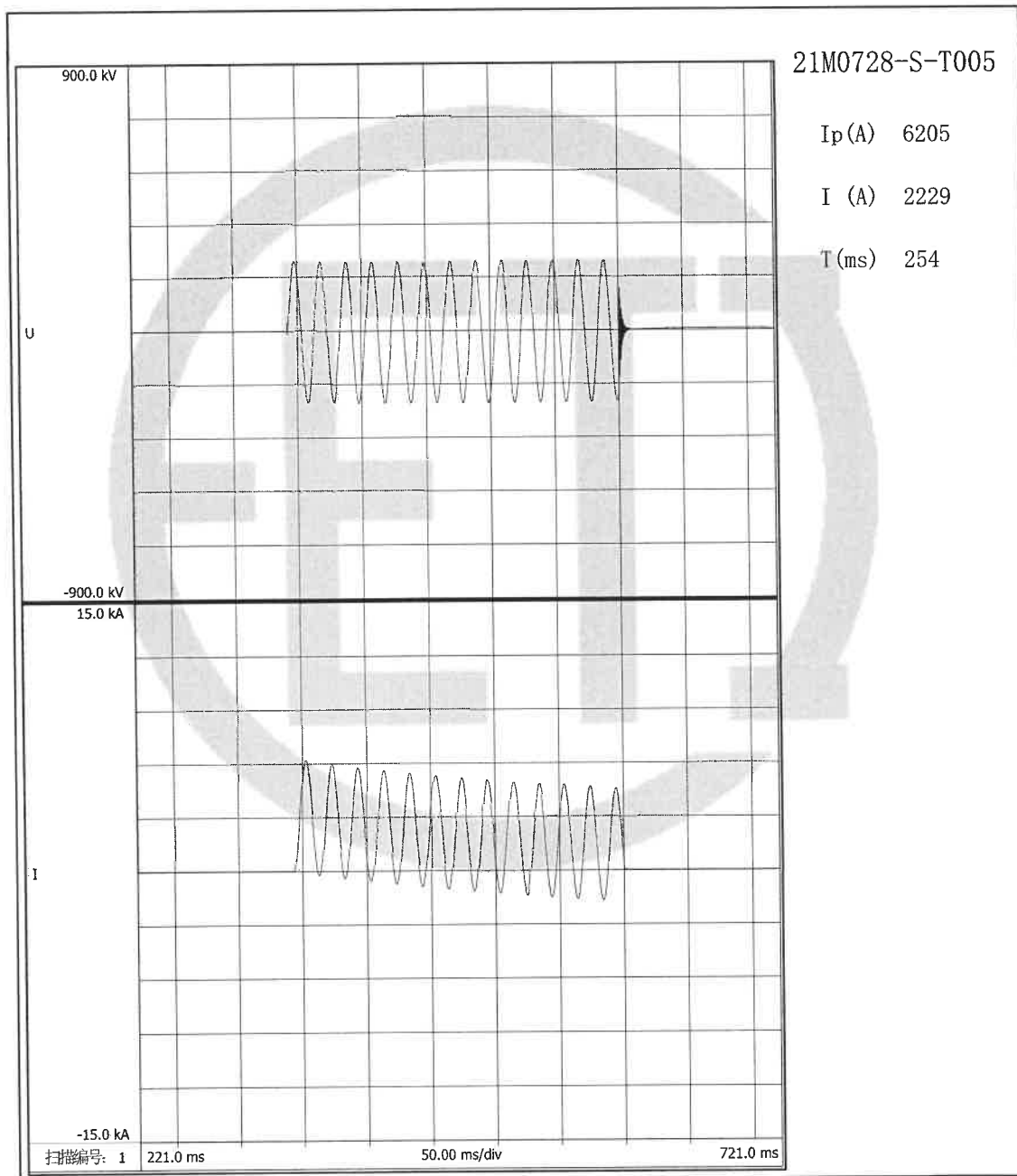
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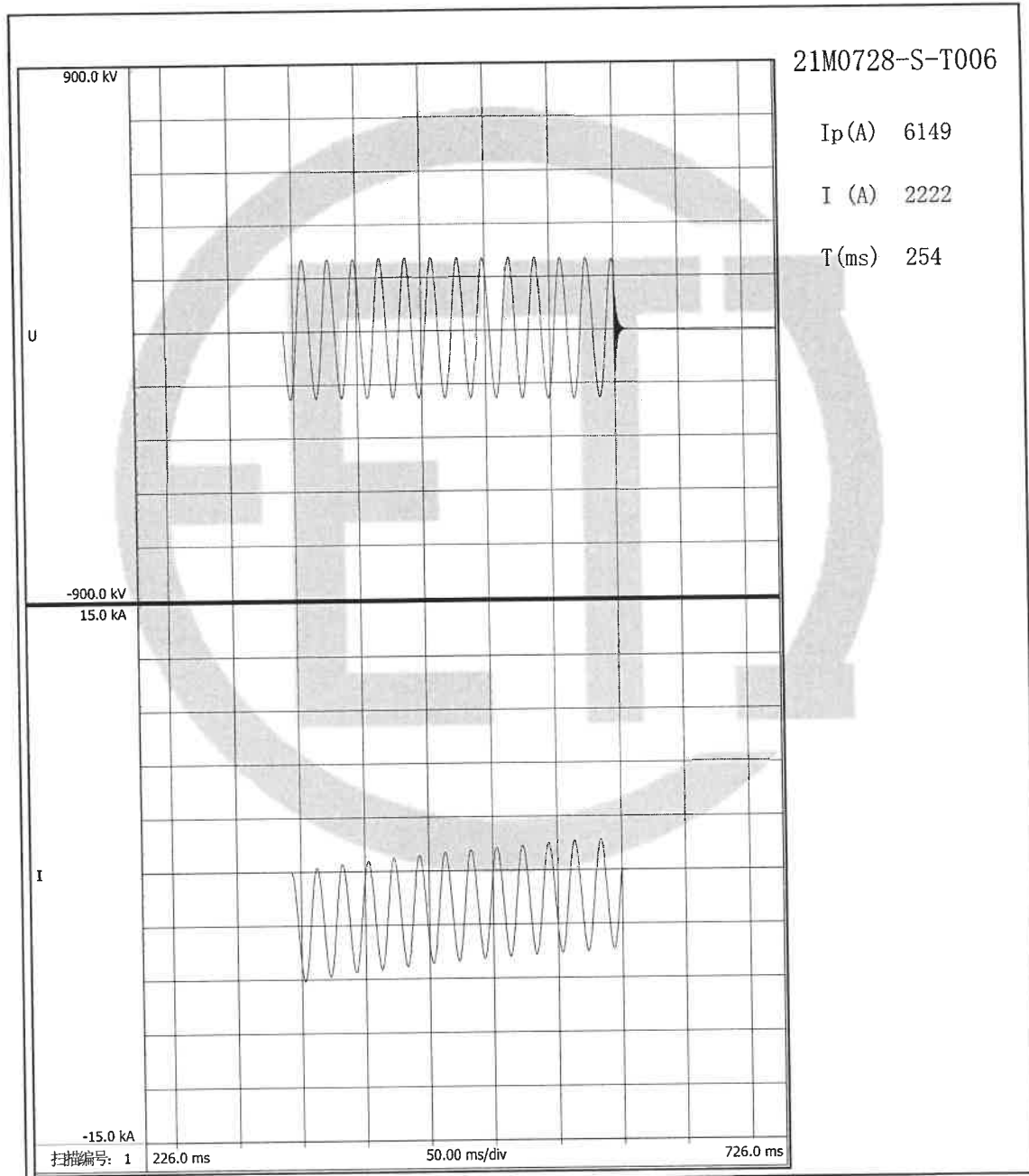
Oscillogram



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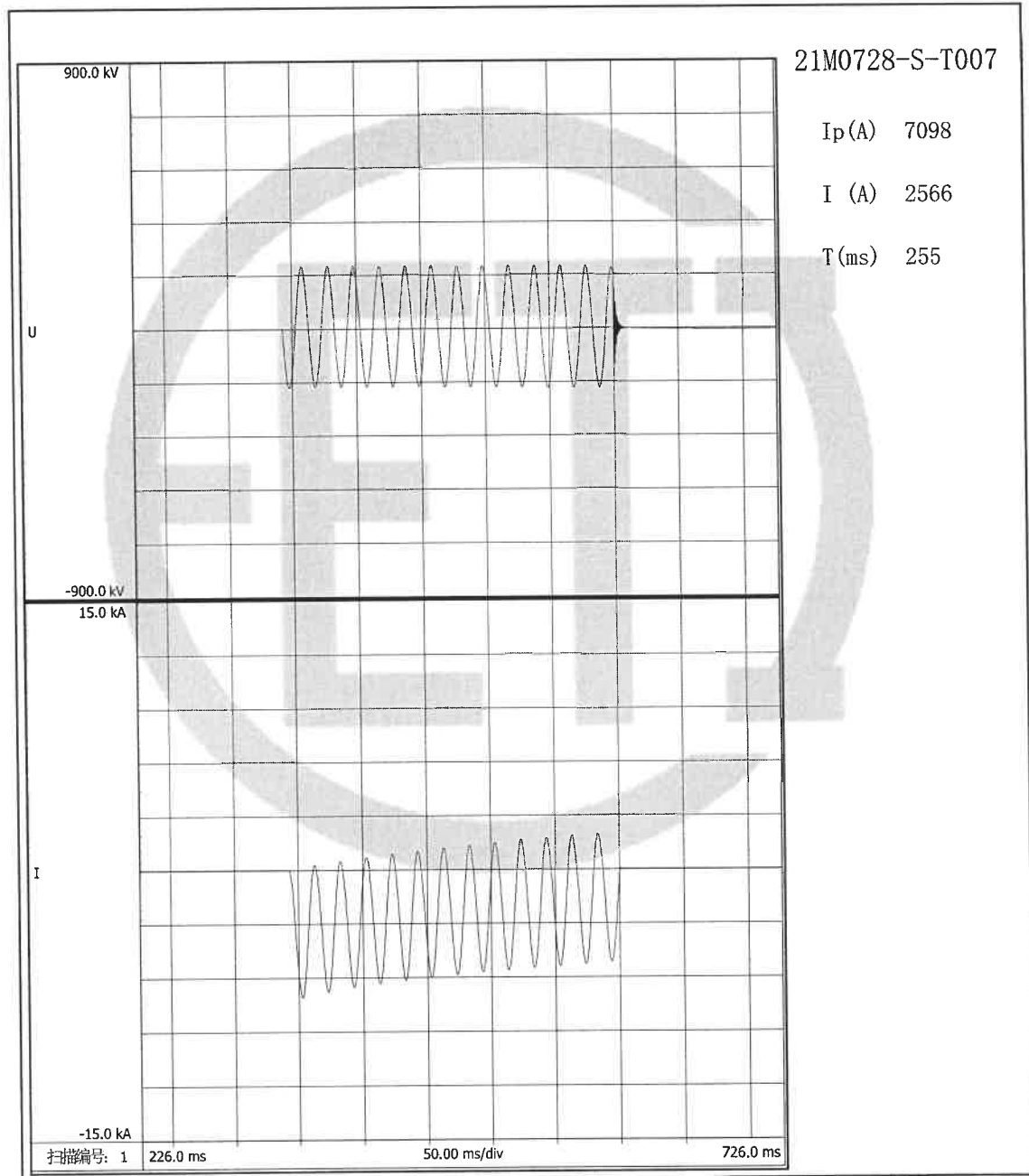
Oscillogram



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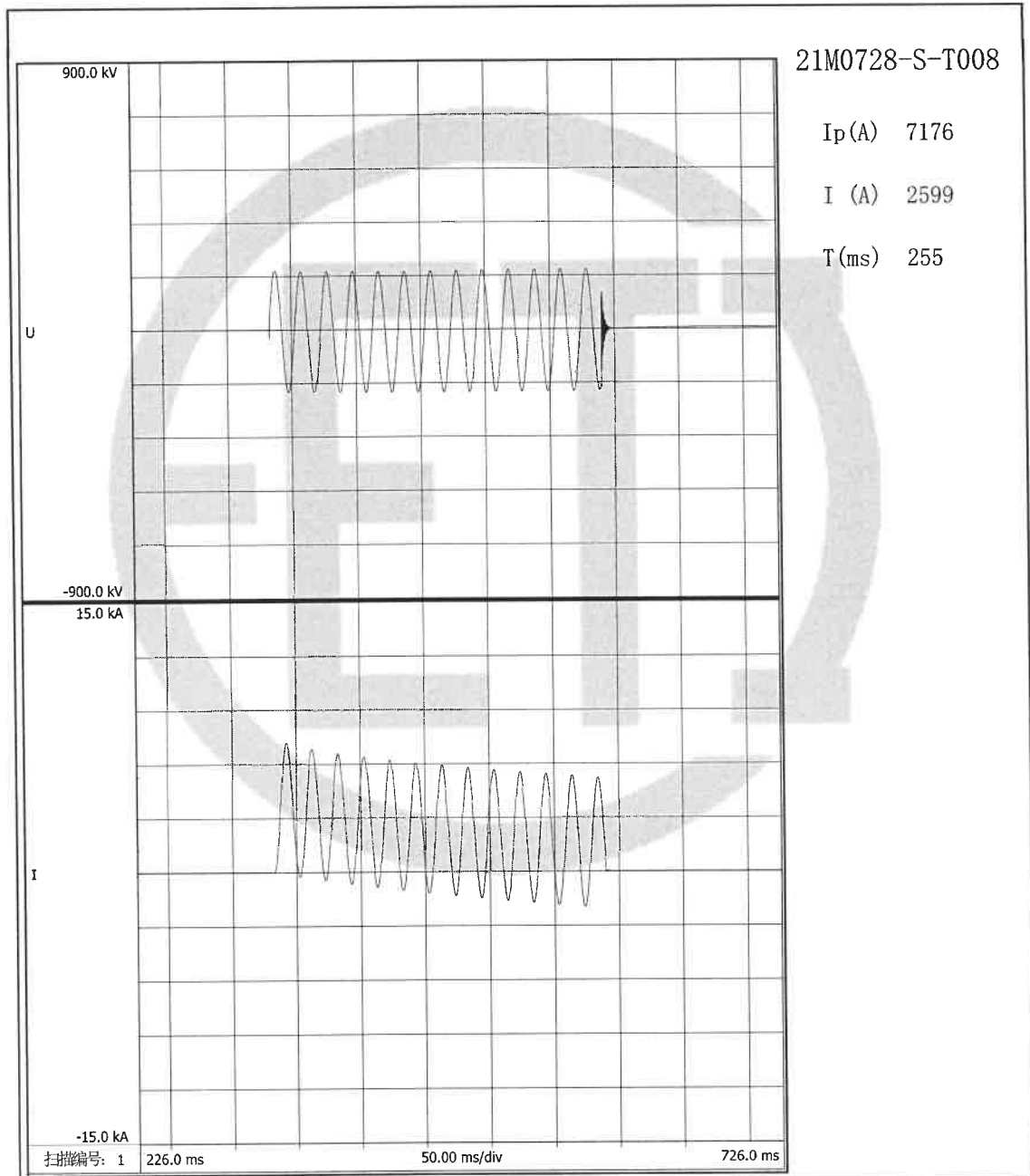
Oscillogram



Test Report

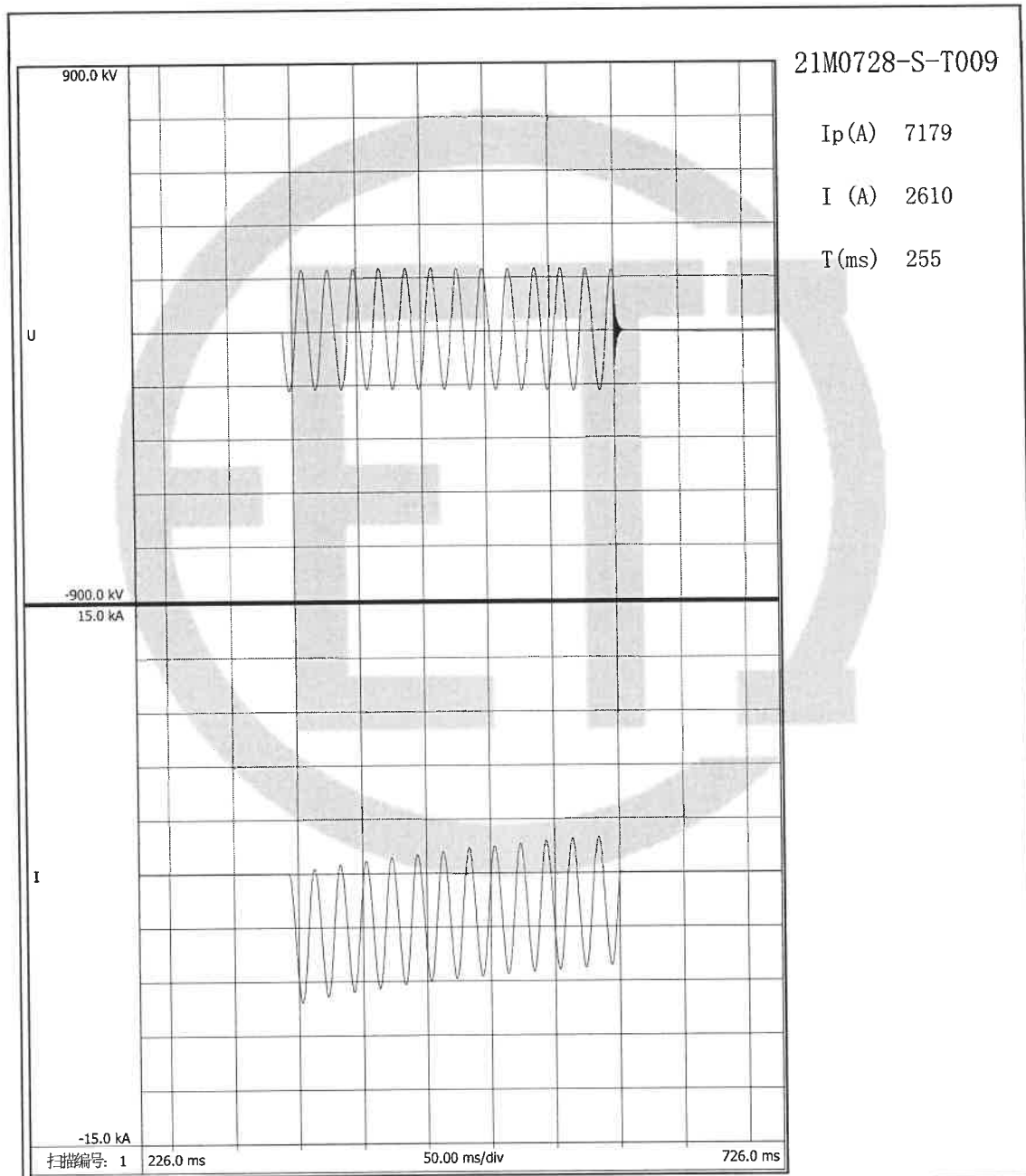
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Oscillogram



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Oscillogram



Test Report	China National Center for Quality Supervision and Test of Electrical Apparatus Products		№: 21M0728-S Total 108 Page 40					
4.21.2 HV-MV short-circuit test Test date: Mar. 19, 2021								
Single-phase supply should be used, HV neutral point is earthed, and test voltage shall be supplied between one HV line terminal and the neutral point line terminal connected together. MV corresponding phase is connected by short-circuit and earthed, LV is open-circuit, one point of LV is earthed. The test oscillogram shall be normal. For the test oscillogram, see P ₄₃₋₅₁ .								
4.21.2.1 Current calculation of short-circuit test (reference temperature 75°C)								
Tapping position	Symmetrical current value of phase (A)		Peak current value of phase (A)					
1	3336		8974					
9b	3750		10088					
17	4073		10956					
4.21.2.2 Current injection of short-circuit test								
Tapping position /phase category	Applied voltage terminal	Times	Measurement of current					
			Symmetrical current value of phase		Peak current value of phase		Duration (s)	Oscillogram No
Measured values (A)	(%)	Measured values (A)	(%)					
1/A	A-O	The first test	3270	98.02	8982	100.09	0.259	21M0728-S-T010
		The second test	3189	95.59	8758	97.59	0.259	21M0728-S-T011
		The third test	3219	96.49	8796	98.02	0.259	21M0728-S-T012
		Times	Measurement of reactance					
			Reactance values of phase (Ω)		Reactance variation of phase (%)			
		A		A				
		Before tests	36.392		/			
		The first test	36.418		0.071			
		The second test	36.429		0.102			
		The third test	36.432		0.110			
The maximum reactance variation of phase is 0.11%.								

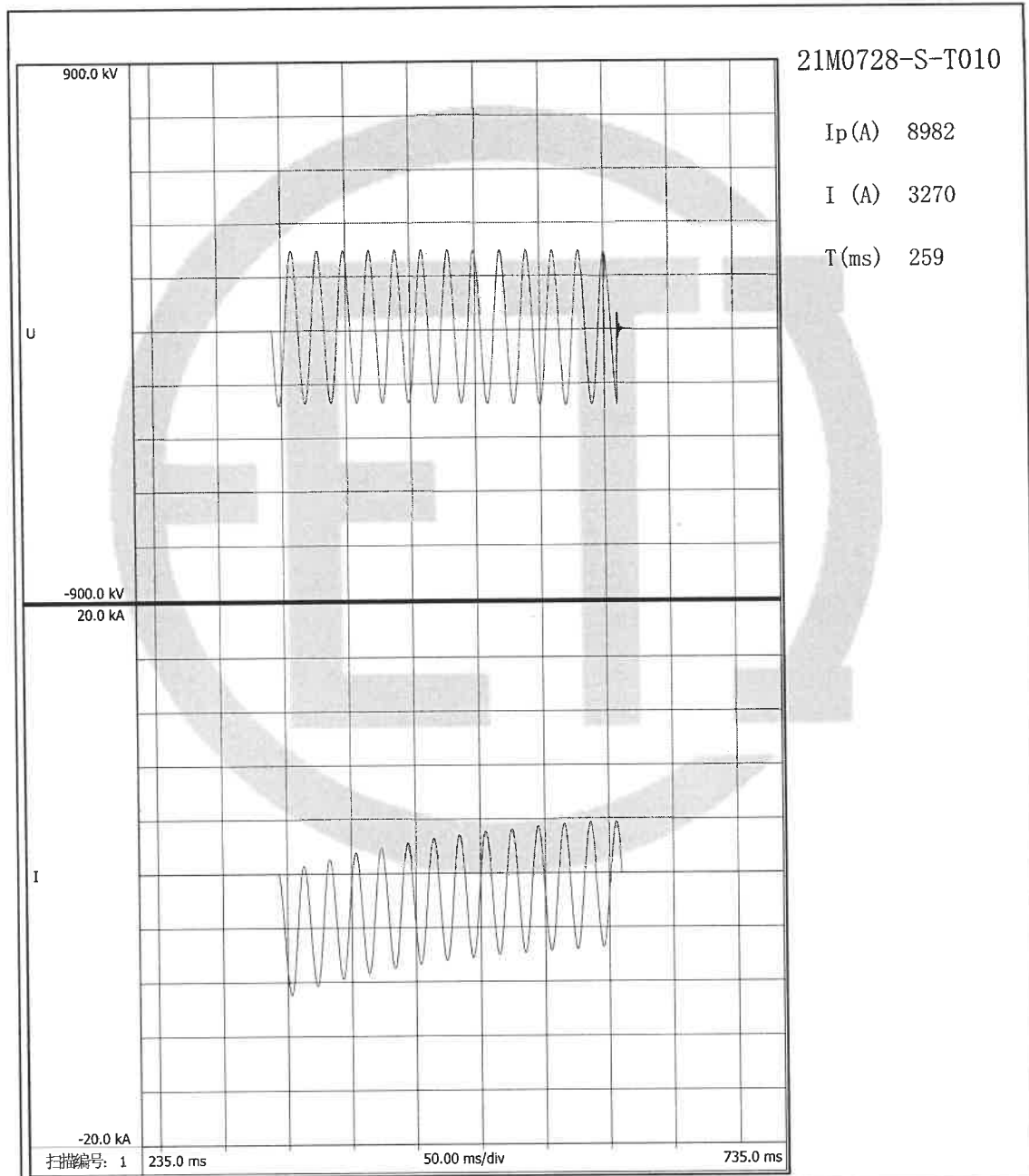
Test Report		China National Center for Quality Supervision and Test of Electrical Apparatus Products				№: 21M0728-S Total 108 Page 41		
Tapping position /phase category	Applied voltage terminal	Times	Measurement of current					
			Symmetrical current value of phase		Peak current value of phase		Duration (s)	Oscillogram No
			Measured values (A)	(%)	Measured values (A)	(%)		
9b/B	B-O	The first test	3655	97.47	10090	100.02	0.260	21M0728-S-T013
		The second test	3705	98.80	10124	100.36	0.260	21M0728-S-T014
		The third test	3665	97.73	10164	100.75	0.259	21M0728-S-T015
		Times	Measurement of reactance					
			Reactance values of phase (Ω)				Reactance variation of phase (%)	
			B				B	
		Before tests	28.473				/	
		The first test	28.505				0.11	
		The second test	28.527				0.19	
		The third test	28.537				0.22	
The maximum reactance variation of phase is 0.22%.								

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Tapping position /phase category	Applied voltage terminal	Times	Measurement of current					
			Symmetrical current value of phase		Peak current value of phase		Duration (s)	Oscillogram No
			Measured values (A)	(%)	Measured values (A)	(%)		
17/C	C-O	The first test	3909	95.97	10958	100.02	0.259	21M0728-S-T016
		The second test	3969	97.45	10974	100.16	0.259	21M0728-S-T017
		The third test	3909	95.97	10996	100.37	0.258	21M0728-S-T018
		Times	Measurement of reactance					
			Reactance values of phase (Ω)				Reactance variation of phase (%)	
			C				C	
		Before tests	22.649				/	
		The first test	22.708				0.26	
		The second test	22.731				0.36	
		The third test	22.741				0.41	
The maximum reactance variation of phase is 0.41%. 4.21.3 The appearance and out-of-tank inspection The appearance inspection without abnormality, the out-of-tank inspection does not reveal any obvious distortion and displacement of coil, lead and supporting structures after the short-circuit test and no traces of discharge are found. For the pictures before and after the short-circuit test, see P₉₈₋₉₉.								

Test Report

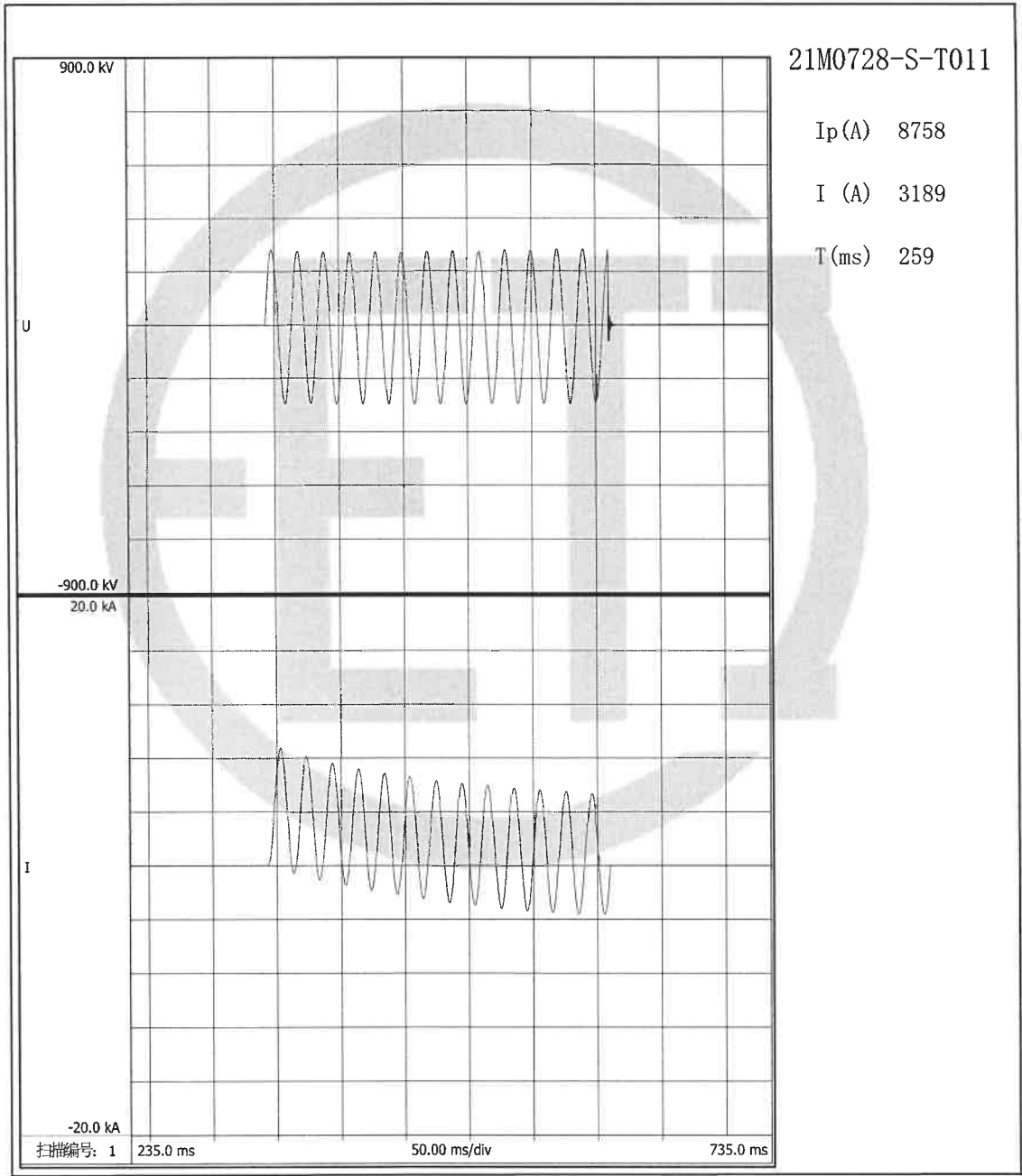
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Oscillogram



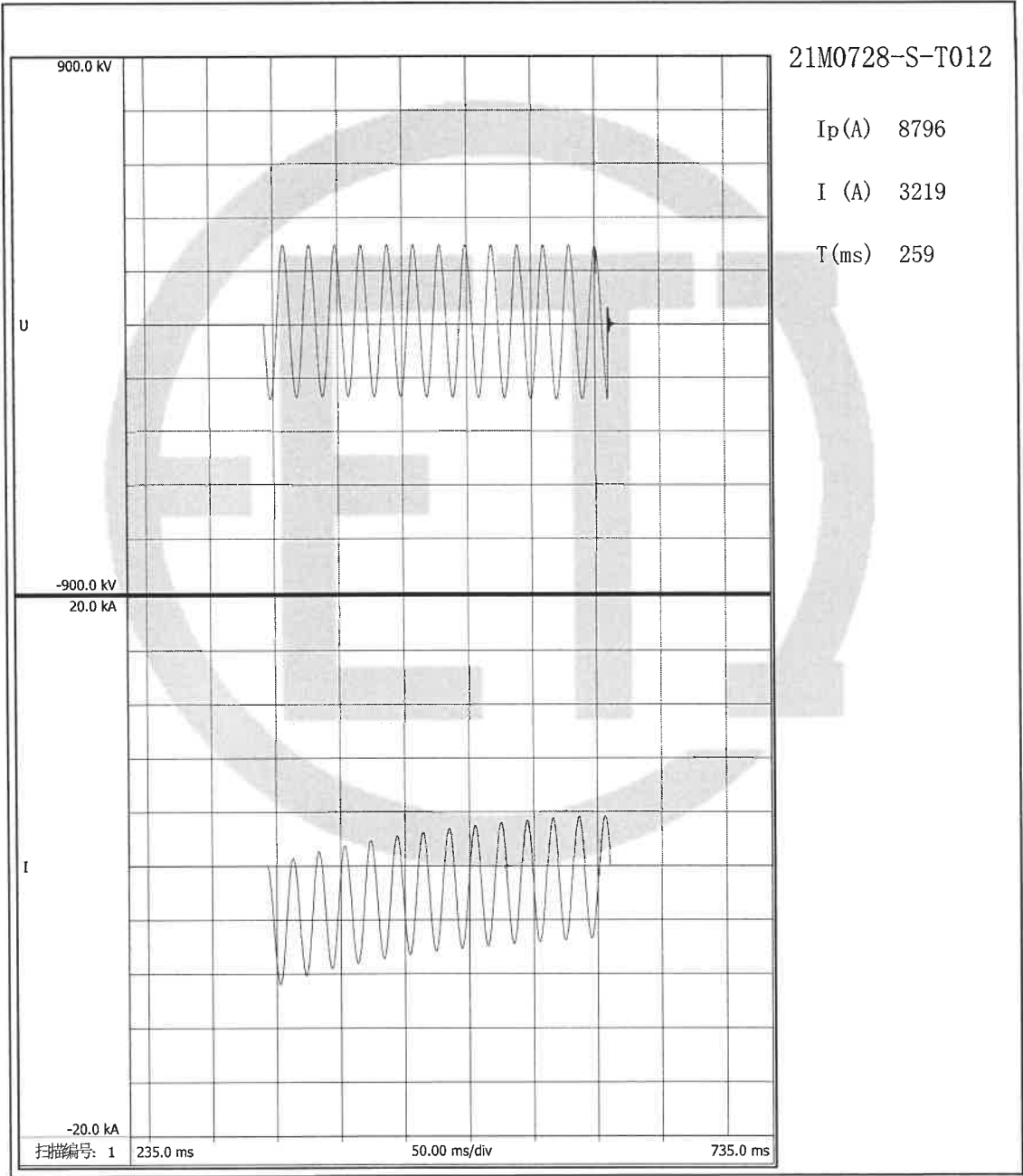
Test Report	China National Center for Quality Supervision and Test of Electrical Apparatus Products	№: 21M0728-S Total 108 Page 44
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Oscillogram



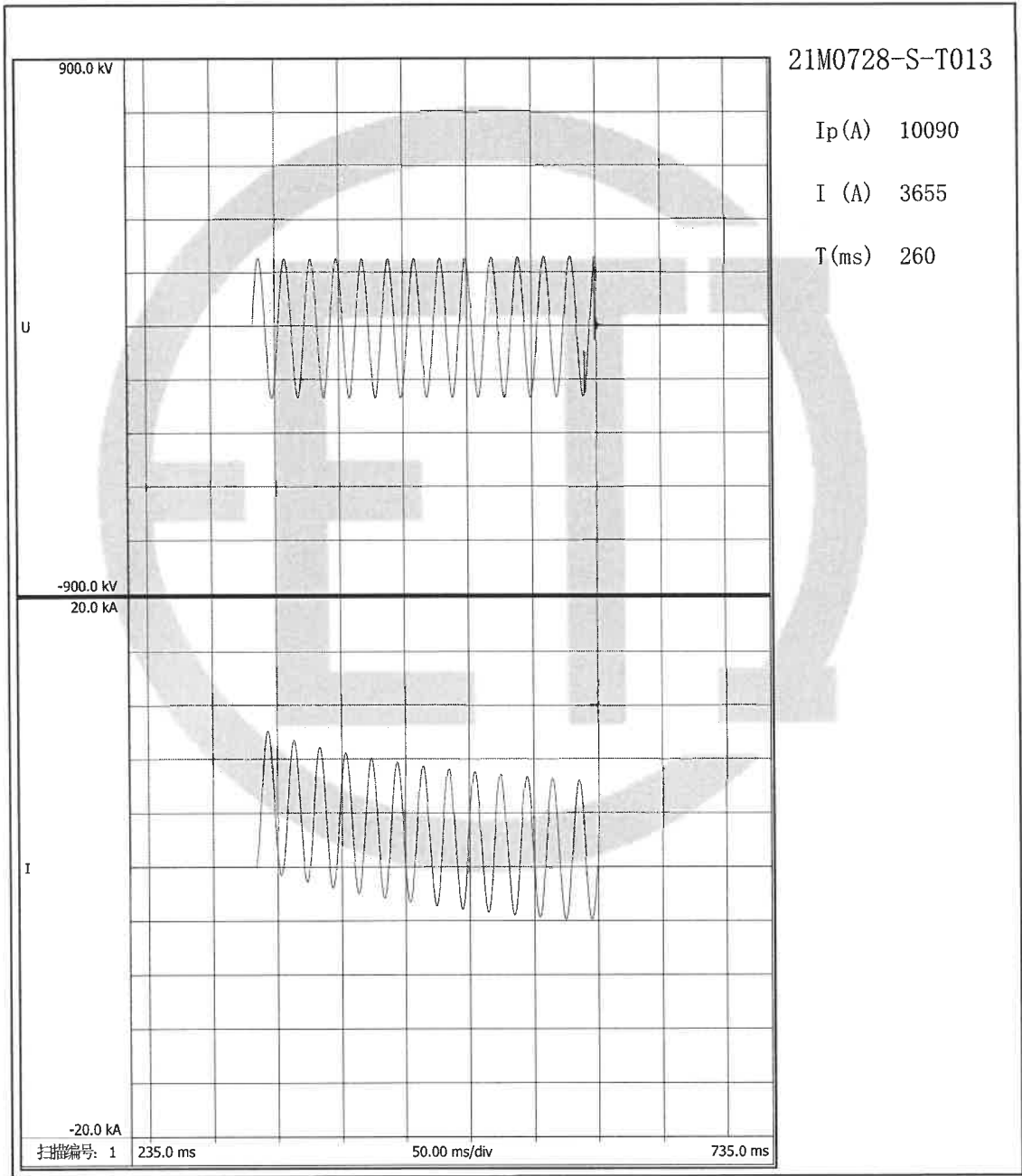
Test Report	China National Center for Quality Supervision and Test of Electrical Apparatus Products	№: 21M0728-S Total 108 Page 45
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Oscillogram



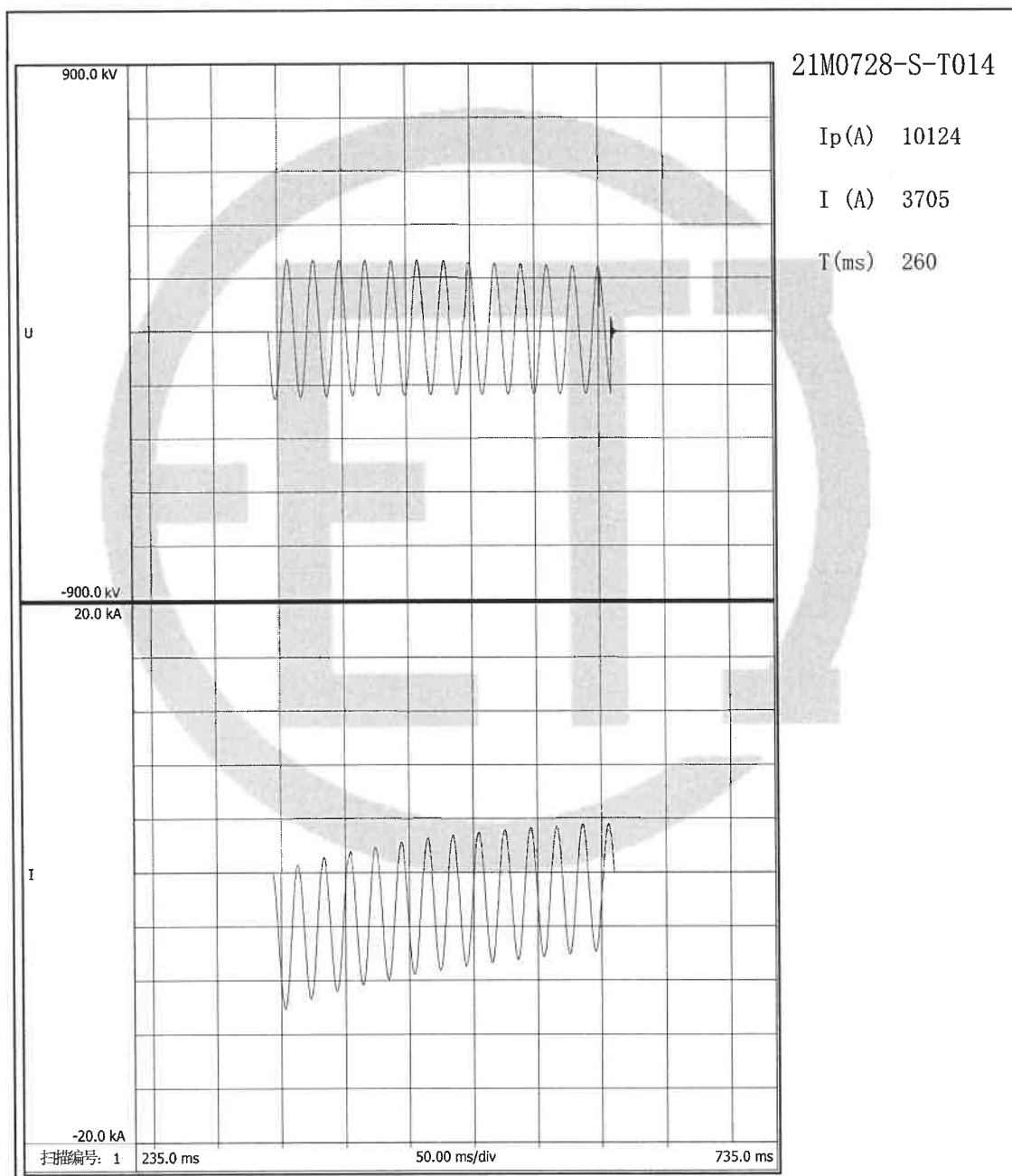
Test Report	China National Center for Quality Supervision and Test of Electrical Apparatus Products	№: 21M0728-S Total 108 Page 46
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Oscillogram



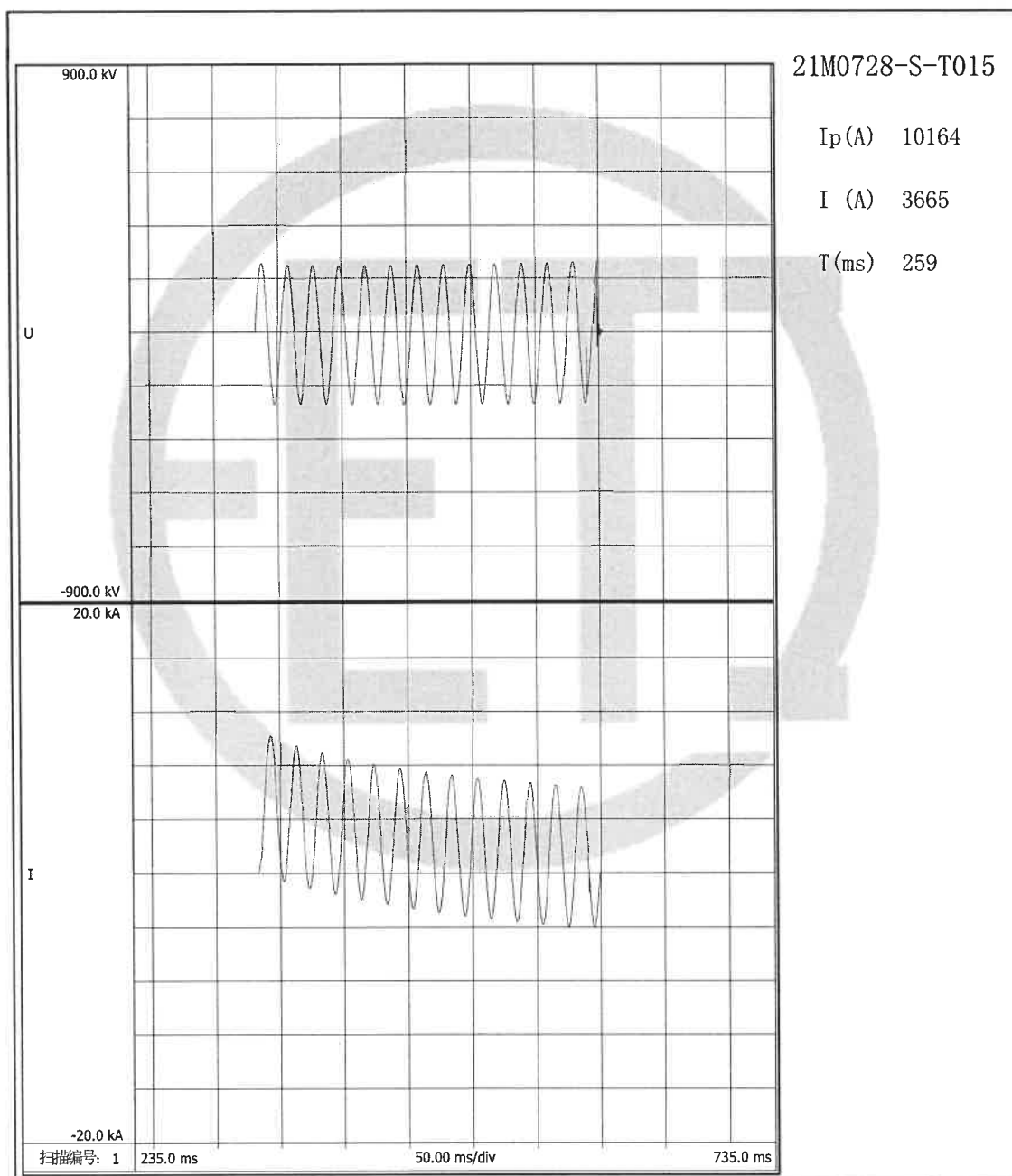
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Oscillogram



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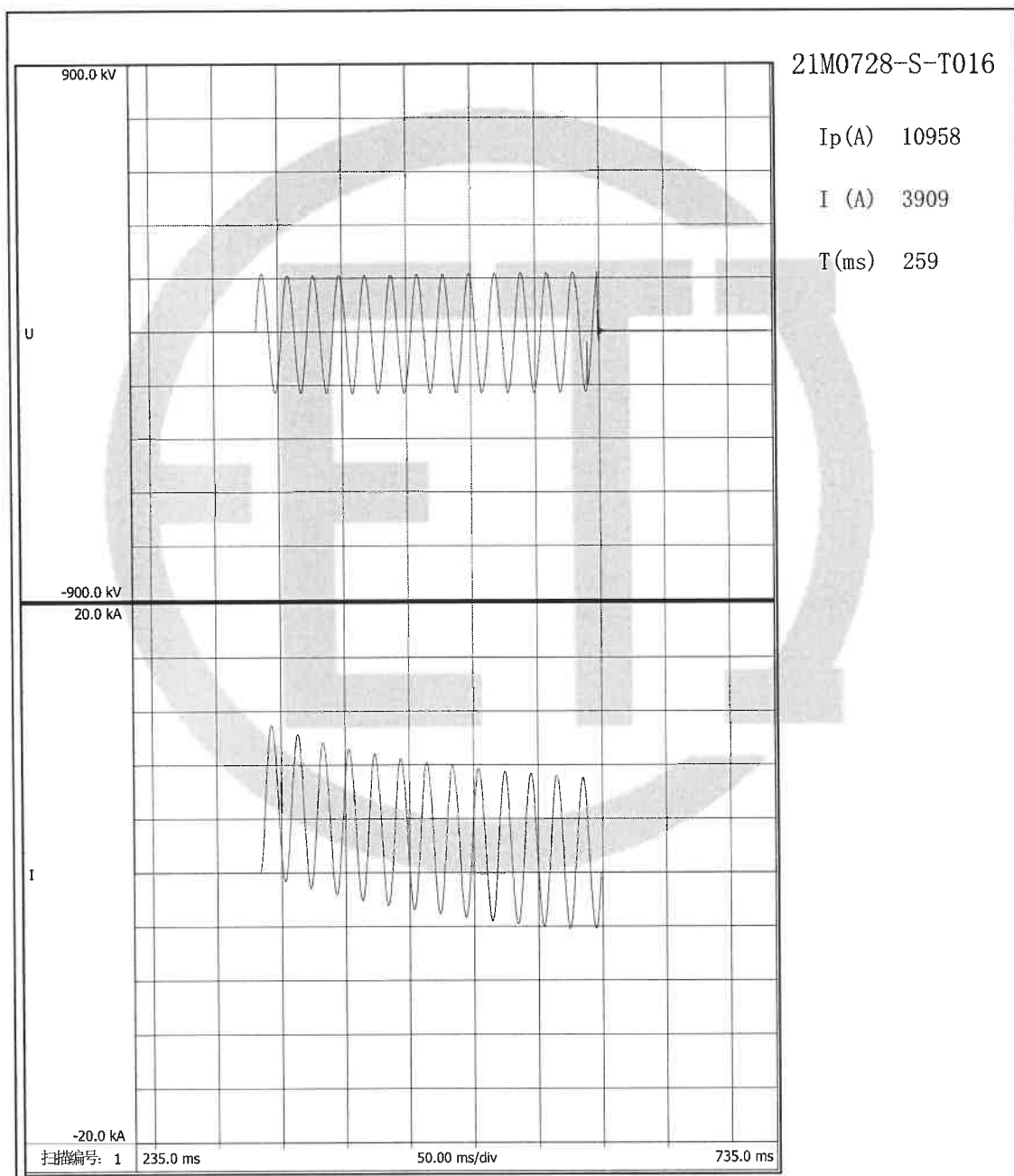
Oscillogram



Test Report

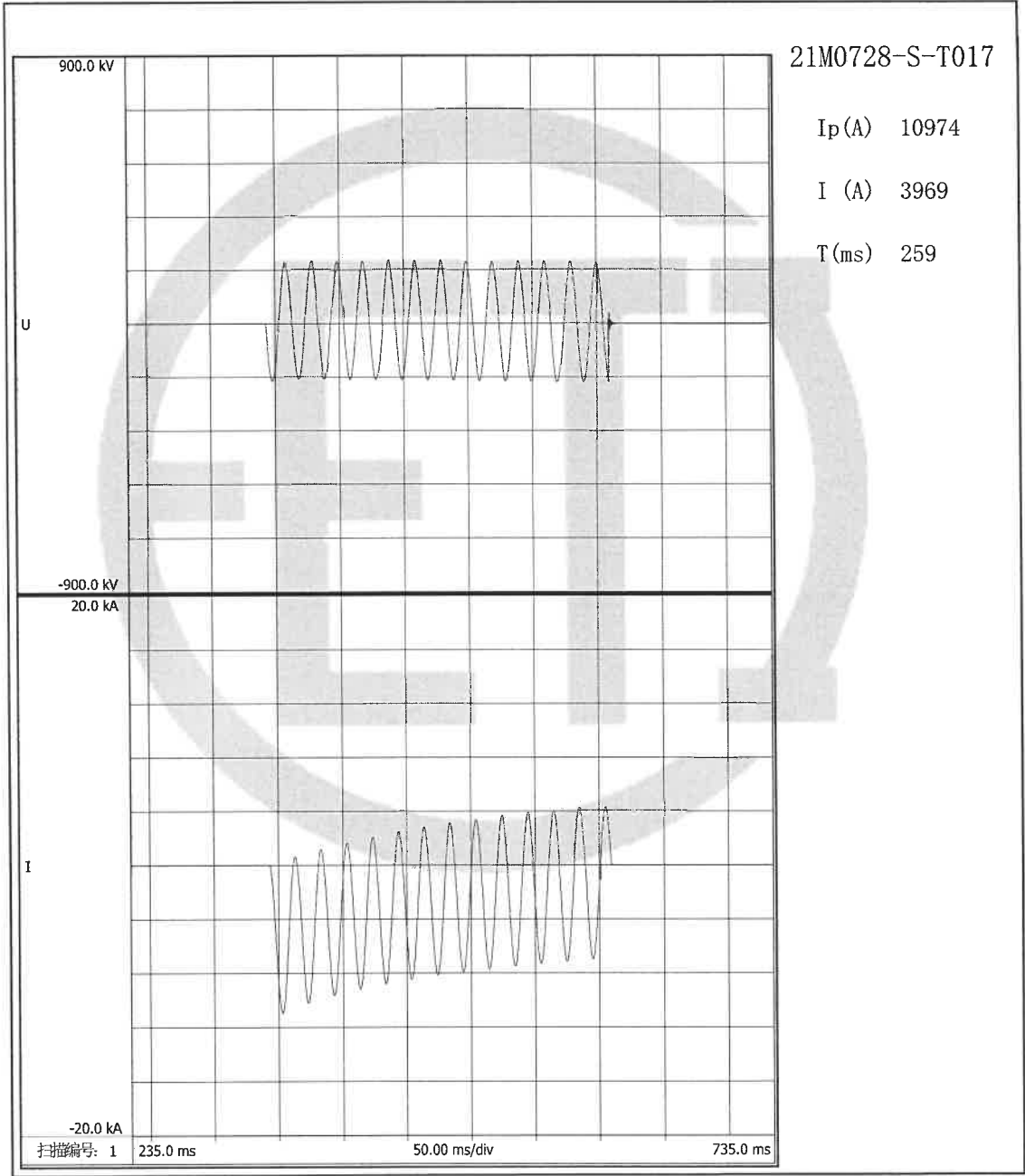
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Oscillogram



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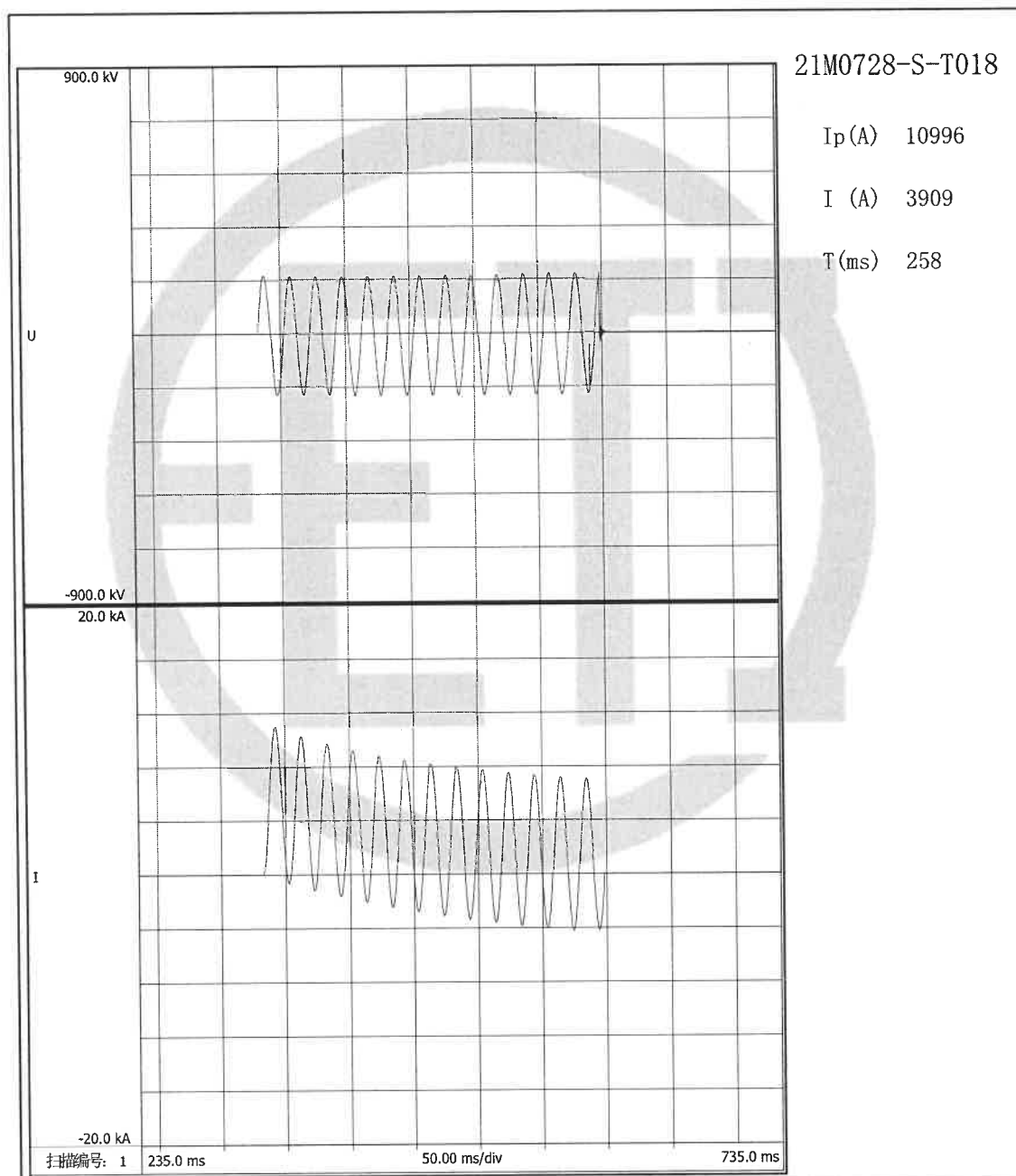
Oscillogram



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Oscillogram



Test Report	China National Center for Quality Supervision and Test of Electrical Apparatus Products			№: 21M0728-S Total 108 Page 52	
4.21.4 Routine retests					
4.21.4.1 Measurement of d.c. insulation resistance windings-to-earth and between windings (routine test)					
Test date: Mar. 21, 2021 Relative humidity: 52%; Oil temperature: 15.1°C					
Measured parts	R ₁₅ (GΩ)	R ₆₀ (GΩ)	R ₆₀₀ (GΩ)	Absorption ratio (R ₆₀ /R ₁₅)	Polarity index (R ₆₀₀ /R ₆₀)
HV—MV, LV and earth	4.02	5.22	8.01	1.30	1.53
MV—HV, LV and earth	4.47	5.97	8.87	1.34	1.49
LV—HV, MV and earth	5.21	6.89	10.5	1.32	1.52
HV, MV, LV—earth	5.48	7.47	11.3	1.36	1.51
HV, MV—LV and earth	4.93	6.22	9.59	1.26	1.54
HV—LV	4.72	6.08	9.54	1.29	1.57
MV—LV	4.45	5.66	9.28	1.27	1.64
HV—MV	4.13	5.41	8.54	1.31	1.58
4.21.4.2 Check of core and frame insulation for liquid-immersed transformers with core or frame insulation (routine test)					
Test date: Mar. 21, 2021 Relative humidity: 52%; Oil temperature: 15.1°C					
Measured parts	Measured insulation resistance (GΩ)		Insulation resistance corrected to 20°C (GΩ)		
Core—earth	2.78		2.28		
Frame—earth	2.89		2.37		
Core—frame	3.66		3.00		
4.21.4.3 Measurement of dissipation factor (tanδ) of the insulation system capacitances (routine test)					
Test date: Mar. 21, 2021 Relative humidity: 52%; Oil temperature: 15.1°C					
Measured parts	Dielectric dissipation factor corrected to 20°C tanδ (%)		Capacitance (pF)		
HV—MV, LV and earth	0.33		16400		
MV—HV, LV and earth	0.33		30470		
LV—HV, MV and earth	0.30		37620		
HV, MV, LV—earth	0.31		29260		
HV, MV—LV and earth	0.33		26670		
HV—LV	0.28		9280		
MV—LV	0.28		17510		
HV—MV	0.30		10190		
4.21.4.4 Determination of capacitances windings-to-earth and between windings (routine test)					
Test date: Mar. 21, 2021					
See 4.21.4.3.					

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4.21.4.5 Measurement of bushing capacitances and dielectric dissipation factor (tanδ) (commission test)						
Test date: Mar. 21, 2021						
Relative humidity: 52%; Oil temperature: 15.1°C						
Measured contents	Applied voltage	Measured parts				
		A	B	C	O	
		202004007	202004006	202004005	202004110	
tanδ(%)	10kV	0.32	0.31	0.32	0.33	
Measured capacitance (pF)		358.1	357.8	357.8	285.4	
Measured contents	Applied voltage	Measured parts				
		Am	Bm	Cm	Om	
		202004091	202004093	202004092	202011030	
tanδ(%)	10kV	0.29	0.29	0.28	0.30	
Measured capacitance (pF)		312.4	310.2	311.3	386.0	

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4.21.4.6 Check the ratio and polarity of built-in current transformers (routine test)				Test date: Mar. 21, 2021	
Installation positions	Terminals	Ratio	Polarity		
A	1S1-1S2	600.12	-		
	1S1-1S3	800.10	-		
	2S1-2S2	599.84	-		
	2S1-2S3	799.99	-		
	3S1-3S2	120.12	-		
	3S1-3S3	160.12	-		
B	1S1-1S2	599.91	-		
	1S1-1S3	799.97	-		
	2S1-2S2	600.12	-		
	2S1-2S3	800.84	-		
	3S1-3S2	119.95	-		
	3S1-3S3	160.25	-		
C	1S1-1S2	600.07	-		
	1S1-1S3	800.24	-		
	2S1-2S2	600.05	-		
	2S1-2S3	800.71	-		
	3S1-3S2	120.25	-		
	3S1-3S3	160.41	-		
O	1S1-1S2	200.07	-		
	1S1-1S3	400.01			
	1S1-1S4	600.23			
	2S1-2S2	199.97			
	2S1-2S3	400.37			
	2S1-2S4	600.05	-		
Om	1S1-1S2	200.41	-		
	1S1-1S3	400.32			
	1S1-1S4	599.91			
	2S1-2S2	200.11			
	2S1-2S3	400.25			
	2S1-2S4	600.21	-		

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Installation positions	Terminals	Ratio		Polarity	
Am	1S1-1S2	1250.8		-	
	1S1-1S3	2502.4		-	
	2S1-2S2	1250.7		-	
	2S1-2S3	2500.7		-	
	3S1-3S2	1250.1		-	
	3S1-3S3	2499.2		-	
Bm	1S1-1S2	1249.7		-	
	1S1-1S3	2499.8		-	
	2S1-2S2	1250.1		-	
	2S1-2S3	2499.7		-	
	3S1-3S2	1250.7		-	
	3S1-3S3	2500.4		-	
Cm	1S1-1S2	1249.7		-	
	1S1-1S3	2500.2		-	
	2S1-2S2	1250.3		-	
	2S1-2S3	2500.5		-	
	3S1-3S2	1250.6		-	
	3S1-3S3	2500.4		-	
4.21.4.7 Insulation test of auxiliary wiring (AuxW) (routine test) Test date: Mar. 21, 2021 Relative humidity: 52%; Ambient temperature: 14.1℃; Oil temperature: 15.1℃; Air pressure: 101kPa					
Parts of applied voltage		Test voltage (kV)	Test duration (s)	Result	
Wiring for current transformer secondary windings	A	2.5	60	PASS	
	B				
	C				
	O				
	Am				
	Bm				
	Cm				
	Om				
Wiring for auxiliary power and control circuit	Power for on-load tap-changer	2.0	60		

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4.21.4.8 Measurement of voltage ratio and check of phase displacement (routine test)								Test date: Mar. 21, 2021	
HV winding		LV winding		Transformer ratio by calculation	Measured voltage ratio tolerance (%)			Connection symbol	
Tapping position	Voltage (kV)	Tapping position	Voltage (kV)		AB/ab	BC/bc	CA/ca		
1	242.00	/	38.5	6.286	0.05	0.07	0.07	YNd11	
2	239.25			6.214	0.08	0.09	0.11		
3	236.50			6.143	0.05	0.07	0.07		
4	233.75			6.071	0.03	0.06	0.09		
5	231.00			6.000	0.08	0.10	0.08		
6	228.25			5.929	0.01	0.01	0.02		
7	225.50			5.857	0.03	0.03	0.03		
8	222.75			5.786	0.01	0.01	0.02		
9b	220.00			5.714	0.03	0.05	0.05		
10	217.25			5.643	0.00	0.02	0.02		
11	214.50			5.571	-0.01	0.01	0.01		
12	211.75			5.500	0.05	0.05	0.05		
13	209.00			5.429	0.01	0.01	0.01		
14	206.25			5.357	-0.04	-0.04	-0.02		
15	203.50			5.286	-0.03	-0.03	-0.01		
16	200.75			5.214	0.05	0.03	0.03		
17	198.00			5.143	0.04	0.02	0.04		
MV winding		LV winding		Transformer ratio by calculation	Measured voltage ratio tolerance (%)			Connection symbol	
Tapping position	Voltage (kV)	Tapping position	Voltage (kV)		AmBm/ab	BmCm/bc	CmAm/ca		
/	121	/	38.5	3.143	0.10	0.10	0.10	ynd11	

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HV winding		MV winding		Transforme r ratio by calculation	Measured voltage ratio tolerance (%)			Connection symbol
Tapping position	Voltage (kV)	Tapping position	Voltage (kV)		AB/AmBm	BC/BmCm	CA/CmAm	
1	242.00	/	121	2.000	0.10	0.10	0.10	YNyn0
2	239.25			1.977	-0.01	-0.01	-0.01	
3	236.50			1.954	0.02	0.02	0.02	
4	233.75			1.932	-0.04	-0.04	0.01	
5	231.00			1.909	0.05	0.05	0.05	
6	228.25			1.886	0.03	0.03	0.03	
7	225.50			1.864	0.02	0.02	-0.03	
8	222.75			1.841	0.00	0.06	0.06	
9b	220.00			1.818	0.05	0.05	0.05	
10	217.25			1.795	0.09	0.03	0.03	
11	214.50			1.773	-0.10	-0.04	-0.04	
12	211.75			1.750	0.00	0.00	0.00	
13	209.00			1.727	-0.02	-0.02	-0.02	
14	206.25			1.704	0.03	0.03	0.03	
15	203.50			1.681	-0.05	0.01	0.01	
16	200.75			1.659	-0.01	-0.01	-0.01	
17	198.00			1.636	0.04	0.04	0.04	

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4.21.4.9 Measurement of winding resistance (routine test)					Test date: Mar. 21, 2021 Oil temperature: 15.1℃
Winding	Tapping position	Measured values (Ω)			Resistance unbalance rate (%)
		A~O Am~Om a~b	B~O Bm~Om b~c	C~O Cm~Om c~a	
HV	1	0.1949	0.1948	0.1942	0.36
	2	0.1917	0.1916	0.1910	0.37
	3	0.1890	0.1888	0.1884	0.32
	4	0.1857	0.1856	0.1852	0.27
	5	0.1831	0.1829	0.1824	0.38
	6	0.1798	0.1796	0.1792	0.34
	7	0.1771	0.1769	0.1765	0.34
	8	0.1739	0.1737	0.1733	0.35
	9b	0.1702	0.1701	0.1700	0.12
	10	0.1744	0.1742	0.1738	0.35
	11	0.1770	0.1769	0.1765	0.28
	12	0.1803	0.1802	0.1797	0.33
	13	0.1830	0.1829	0.1824	0.33
	14	0.1862	0.1861	0.1857	0.27
	15	0.1890	0.1889	0.1883	0.37
	16	0.1923	0.1920	0.1916	0.37
	17	0.1949	0.1948	0.1943	0.31
MV	/	39.23×10 ⁻³	39.28×10 ⁻³	39.25×10 ⁻³	0.13
LV	/	12.32×10 ⁻³	12.35×10 ⁻³	12.28×10 ⁻³	0.57

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4.21.4.10 Measurement of no-load loss and current (routine test)					Test date: Mar. 22, 2021			
Voltage multiple	Applied voltage (kV)		No-load current		No-load loss (kW)			
	Average value	r.m.s. value	(A)	(%)	Measured value	Corrected value		
90%U _r	34.646	34.661	1.76	0.05	73.860	73.828		
100%U _r	38.513	38.521	3.56	0.10	96.169	96.148		
110%U _r	42.355	42.351	18.87	0.52	121.684	121.695		
Remarks: at 100%U _r , the difference between r.m.s. voltage and average voltage is within 3%.								
4.21.4.11 Measurement of no-load loss and current at 90% and 110% of rated voltage (routine test) See 4.21.4.10.								
4.21.4.12 Measurement of short-circuit impedance and load loss (routine test)					Test date: Mar. 22, 2021 Oil temperature: 14.0°C			
Winding	Tapping position	Applied current I		Measured voltage (kV)	Short-circuit impedance (for each phase)		Load loss (kW)	Total loss (kW)
		(A)	I/I _r (%)		HV impedance (Ω)	(%)	Corrected value	Corrected value
					t=75°C I=I _r	t=75°C I=I _r	t=75°C I=I _r	t=75°C I=I _r
HV LV	1	152.75	53.35	16.341	61.77	25.31	212.432	308.580
	9b	170.25	54.06	14.561	49.38	24.49	224.494	320.642
	17	191.01	54.59	12.536	37.90	23.20	239.367	335.515
HV MV	1	340.21	59.42	21.519	36.52	14.97	562.851	658.999
	9b	353.42	56.11	17.448	28.51	14.14	647.421	743.569
	17	390.22	55.76	15.333	22.69	13.89	759.836	855.984
MV LV	/	300.64	52.50	2.653	5.10	8.36	144.865	241.013

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4.21.4.13 Tests on on-load tap-changers (routine test) Test date: Mar. 22, 2021 Operation tests: a. with the transformer de-energized, eight complete cycles of operation (a cycle of operation goes from one end of the tapping range to the other, and back again); b. with the transformer de-energized, and with the auxiliary voltage reduced to 85 % of its rated value, one complete cycle of operation; c. with the transformer energized at rated voltage and frequency at no load, one complete cycle of operation; d. with one winding short-circuited and, as far as practicable, rated current in the tapped winding, 10 cycles of tap-change operations across the range of two steps on each side from where a coarse or reversing changeover selector operates, or otherwise from the middle tapping (the tapchanger will pass 20 times through the changeover position). Test result: PASS		

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4.21.4.14 Lightning impulse test (LI, LIC, LIN) (routine test, type test) Test date: Mar. 22, 2021																					
Atmospheric conditions of test: Relative humidity: 29%; Ambient temperature: 13.4℃; Oil temperature: 14.3℃; Air pressure: 101kPa.																					
Test items and voltage																					
Withstand terminals	Rated withstand voltage (kV)		Tapping position																		
	Lightning full wave	Lightning chopped wave																			
A, B, C	950	1050	A:1; B:9b; C:17																		
O	400	/	1																		
Am, Bm, Cm	480	530	/																		
Om	325	/	/																		
a, b, c	200	220	/																		
Test sequence: Line terminal One negative reduced level full wave impulse; One negative rated level full wave impulse; One negative reduced level chopped impulse; Two negative rated level chopped impulse; Two negative rated level full wave impulse. Neutral point: One negative reduced level full wave impulse; Three negative rated level full wave impulse. Test records: T1: wave front time, T2: time to half peak value, Tc: chopped wave time, Upk: peak voltage. For waveform diagram, see P₆₂~P₇₂. Voltage ranges of oscillograms are as below: <table border="1"> <tr> <th>Withstand terminals</th> <th>Full wave (kV)</th> <th>Chopped wave (kV)</th> </tr> <tr> <td>A, B, C</td> <td>947.12~963.55</td> <td>1031.13~1060.11</td> </tr> <tr> <td>O</td> <td>397.49~401.37</td> <td>/</td> </tr> <tr> <td>Am, Bm, Cm</td> <td>479.92~484.93</td> <td>525.63~530.96</td> </tr> <tr> <td>Om</td> <td>321.34~325.91</td> <td>/</td> </tr> <tr> <td>a, b, c</td> <td>197.30~204.20</td> <td>218.28~221.19</td> </tr> </table>				Withstand terminals	Full wave (kV)	Chopped wave (kV)	A, B, C	947.12~963.55	1031.13~1060.11	O	397.49~401.37	/	Am, Bm, Cm	479.92~484.93	525.63~530.96	Om	321.34~325.91	/	a, b, c	197.30~204.20	218.28~221.19
Withstand terminals	Full wave (kV)	Chopped wave (kV)																			
A, B, C	947.12~963.55	1031.13~1060.11																			
O	397.49~401.37	/																			
Am, Bm, Cm	479.92~484.93	525.63~530.96																			
Om	321.34~325.91	/																			
a, b, c	197.30~204.20	218.28~221.19																			

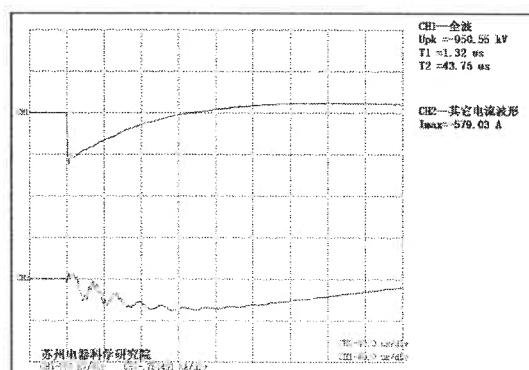
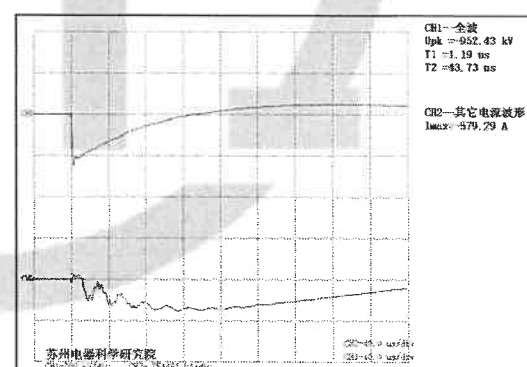
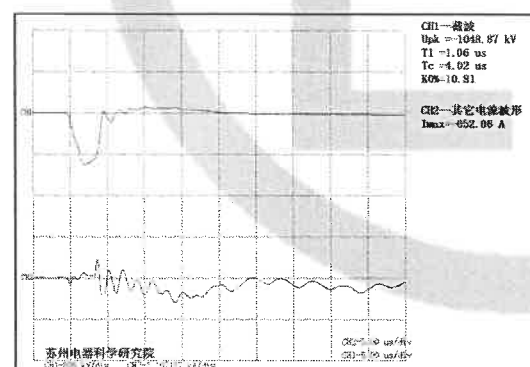
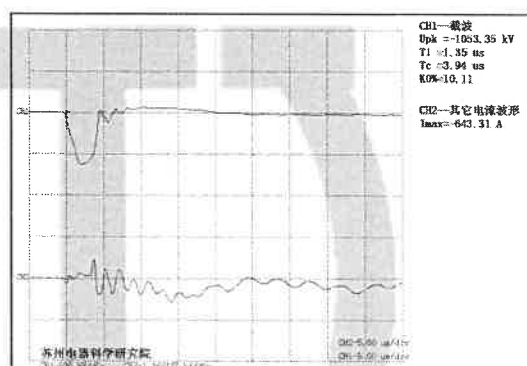
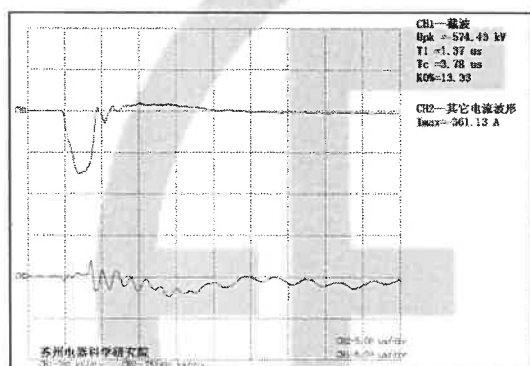
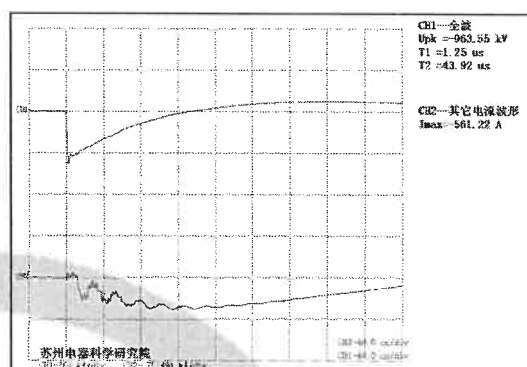
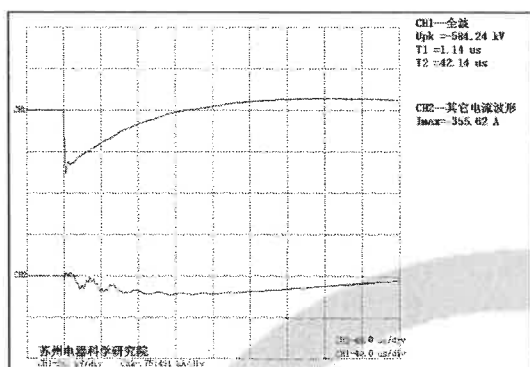
Test Report

China National Center for Quality Supervision and
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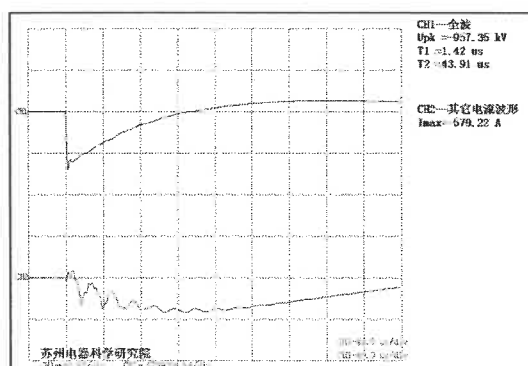
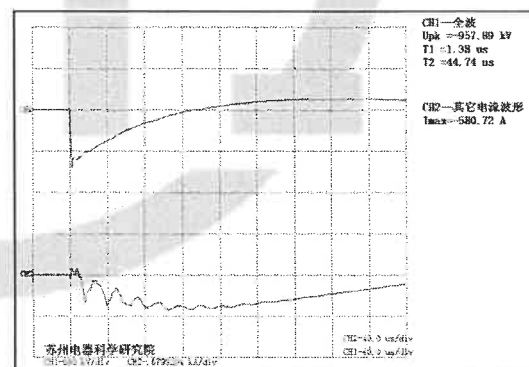
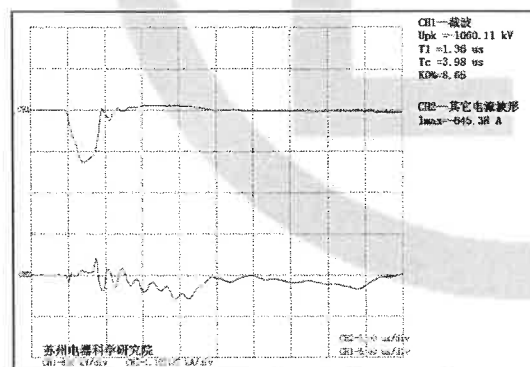
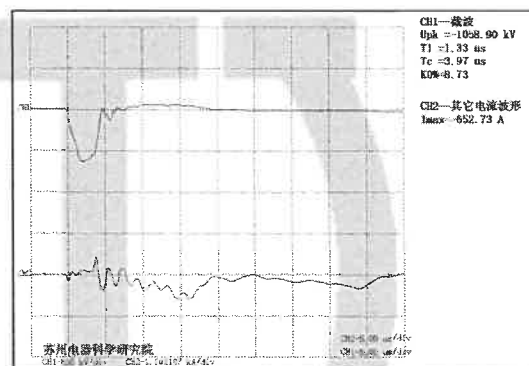
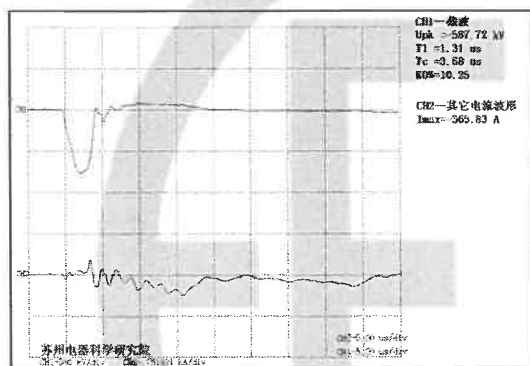
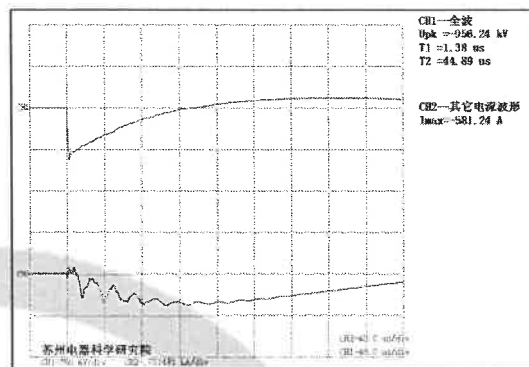
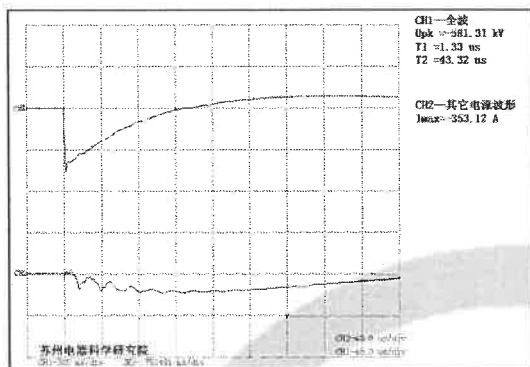
Tested terminal: A Test polarity: negative Channel 1: voltage wave Channel 2: current wave



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Tested terminal: B Test polarity: negative Channel 1: voltage wave Channel 2: current wave



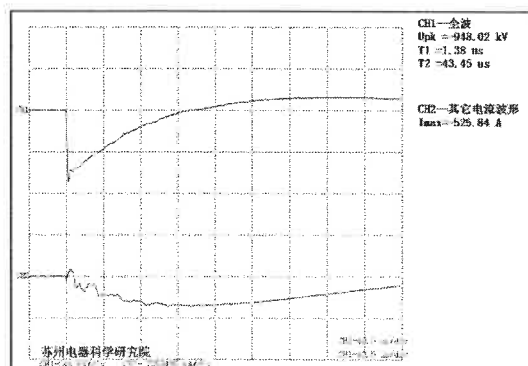
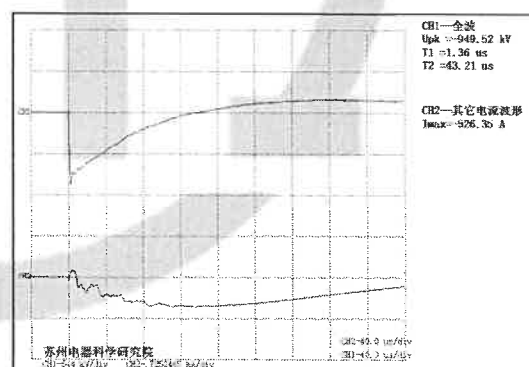
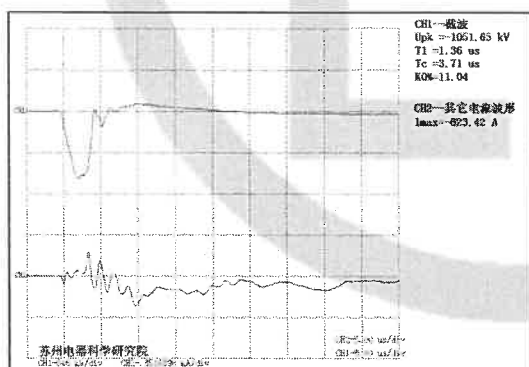
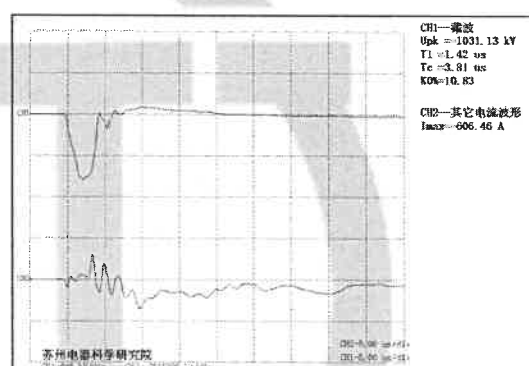
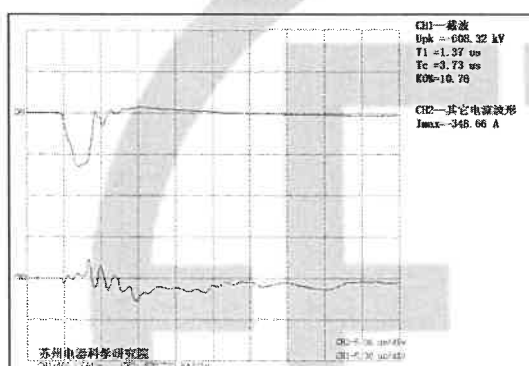
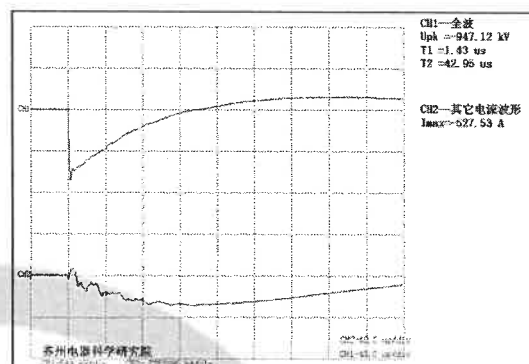
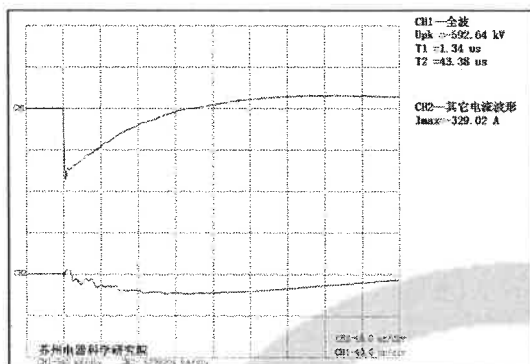
Test Report

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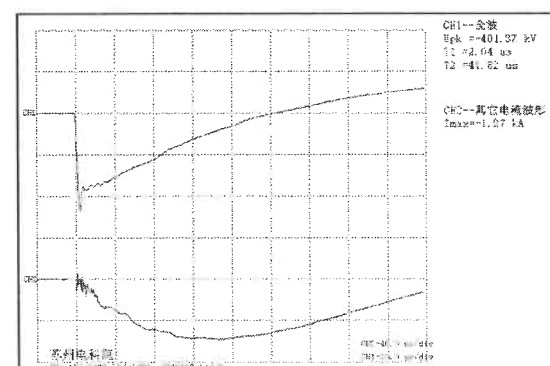
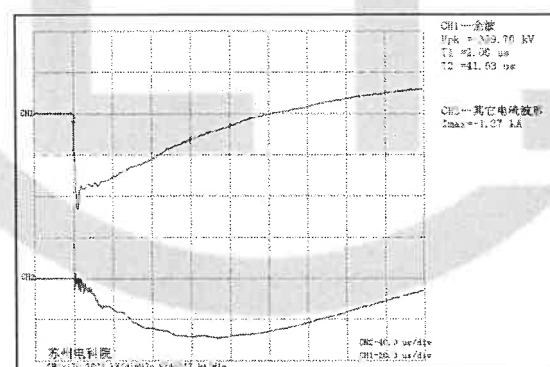
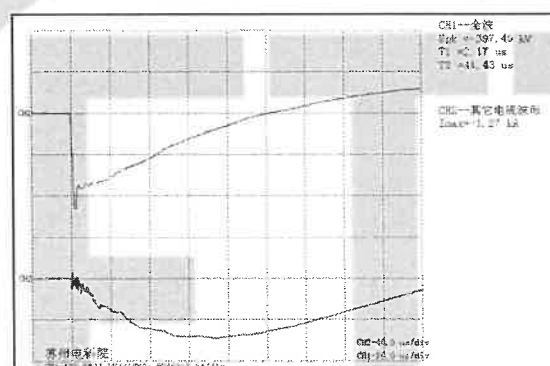
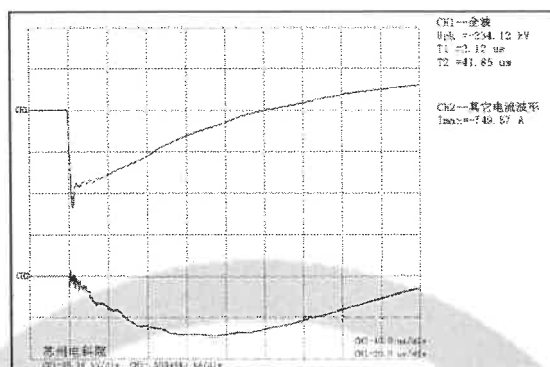
Tested terminal: C Test polarity: negative Channel 1: voltage wave Channel 2: current wave



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Tested terminal: O Test polarity: negative Channel 1: voltage wave Channel 2: current wave



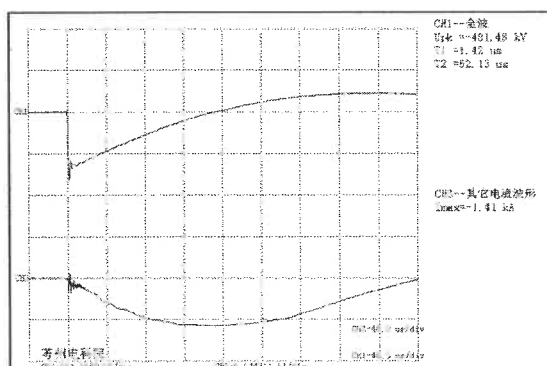
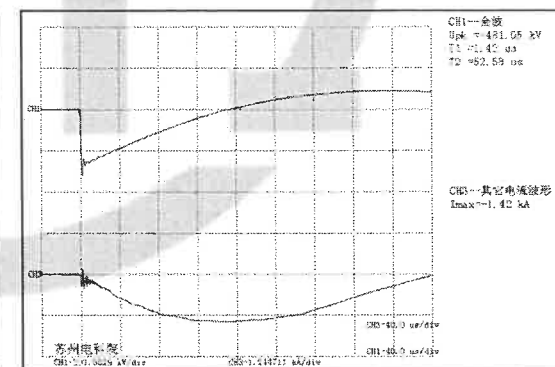
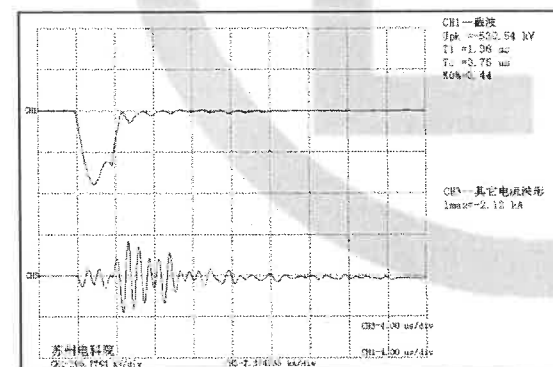
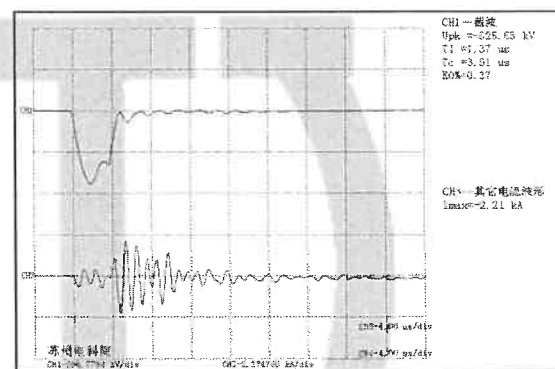
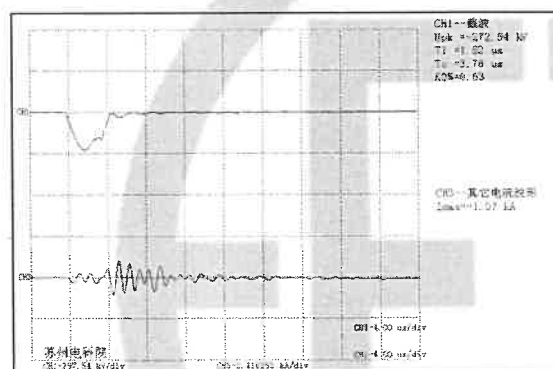
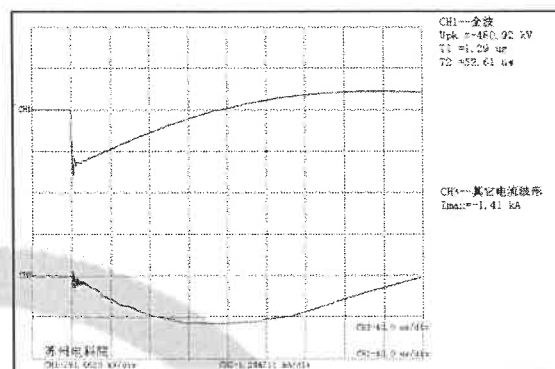
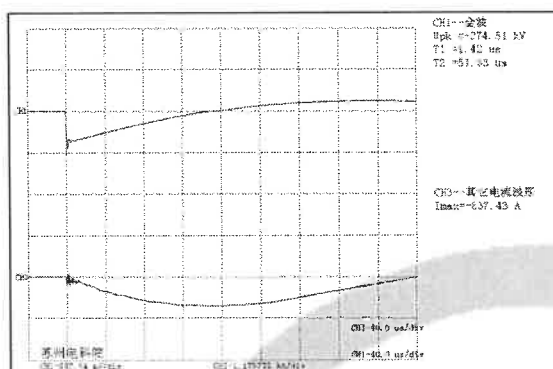
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Tested terminal: Am Test polarity: negative Channel 1: voltage wave Channel 2: current wave

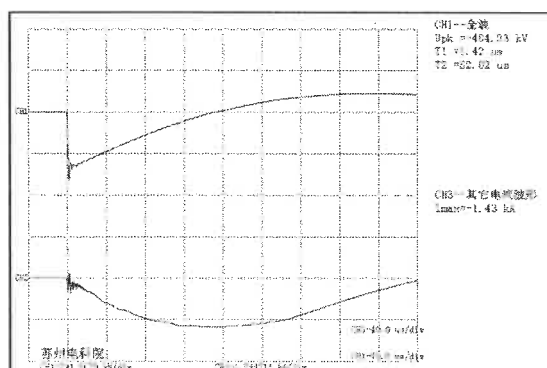
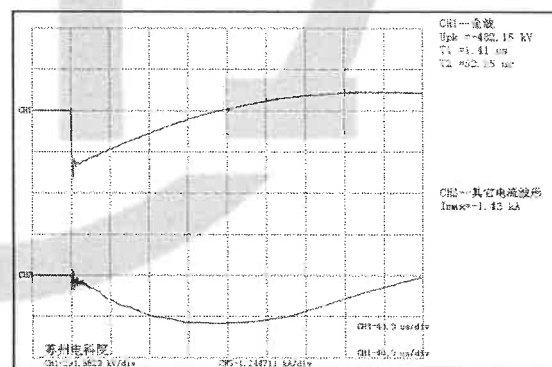
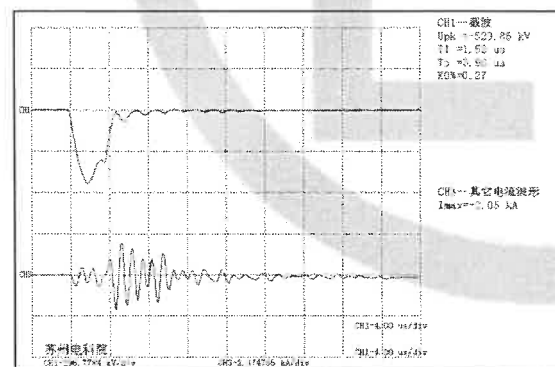
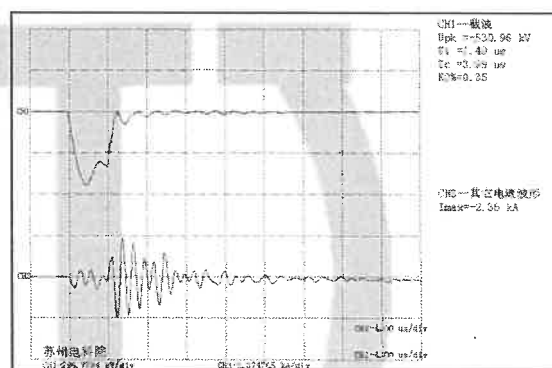
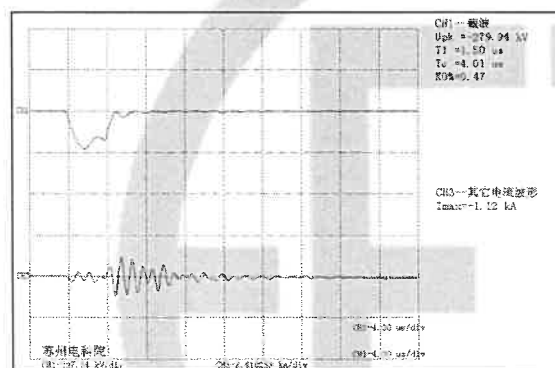
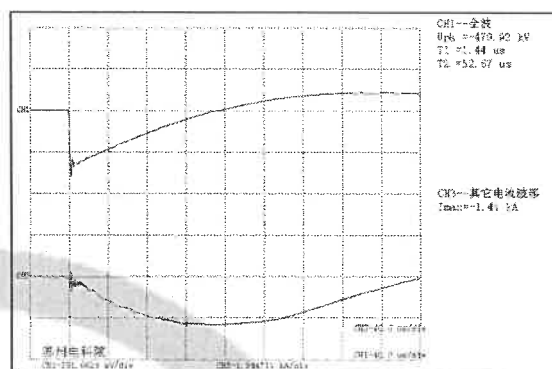
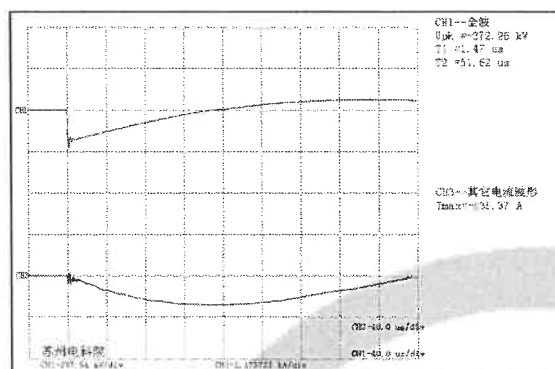


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Tested terminal: Bm Test polarity: negative Channel 1: voltage wave Channel 2: current wave



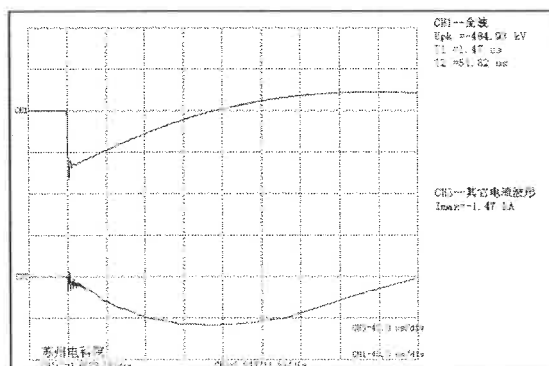
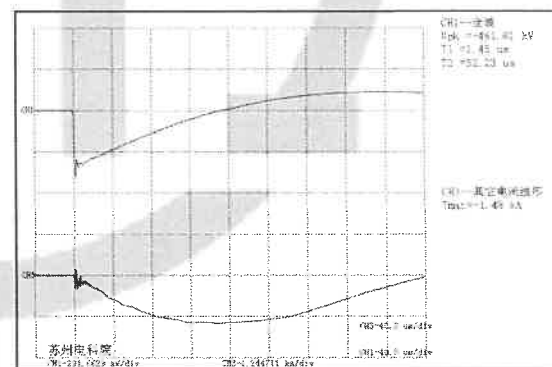
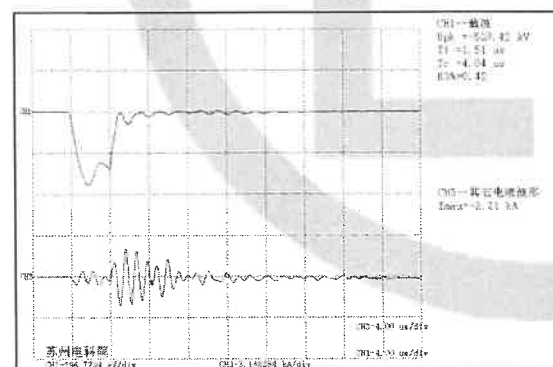
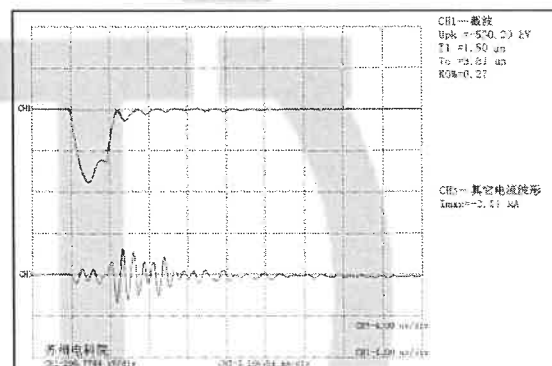
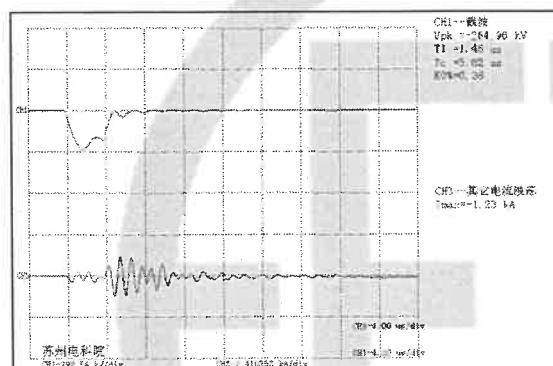
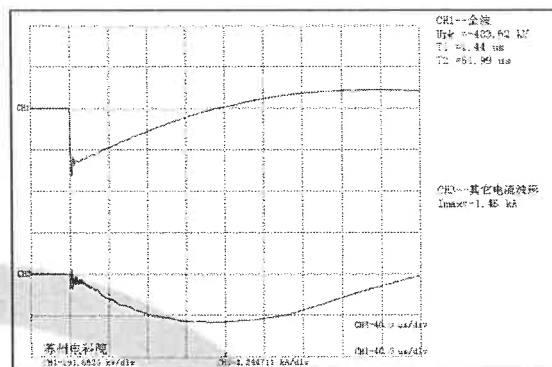
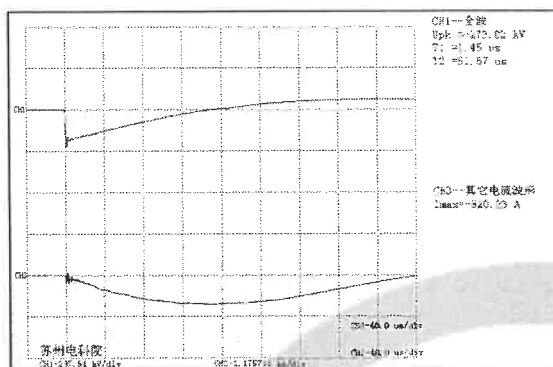
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Tested terminal: Cm Test polarity: negative Channel 1: voltage wave Channel 2: current wave



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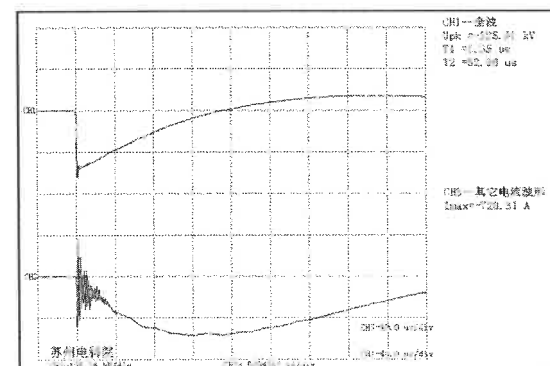
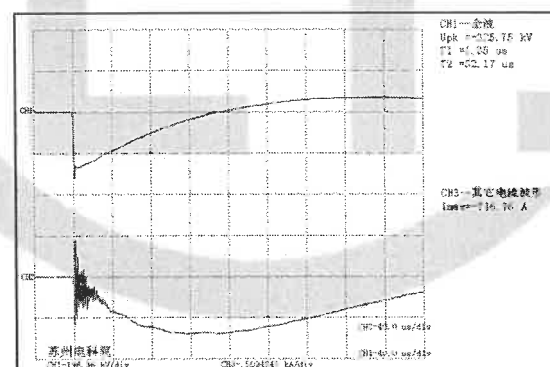
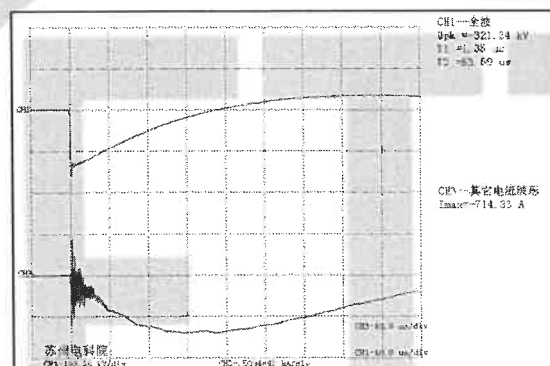
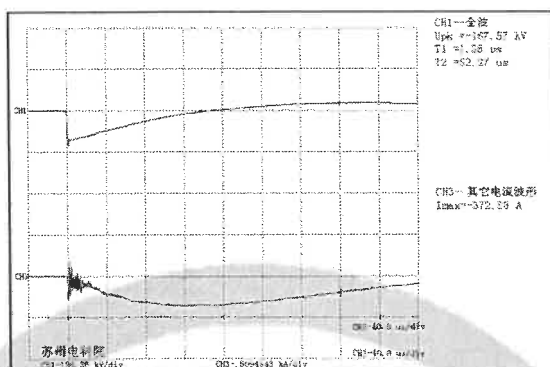
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Tested terminal: Om

Test polarity: negative

Channel 1: voltage wave

Channel 2: current wave



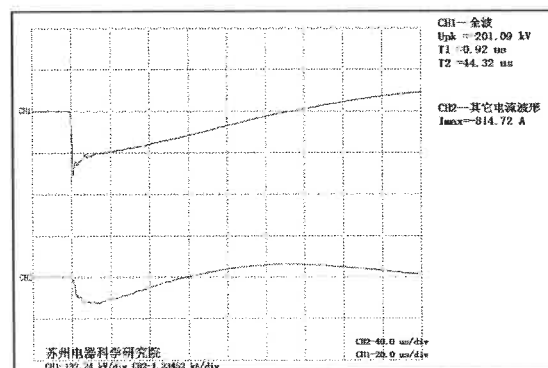
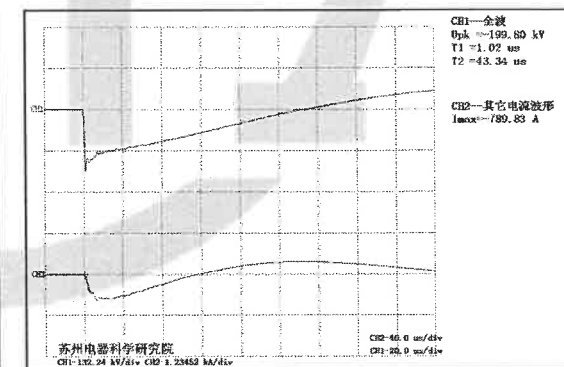
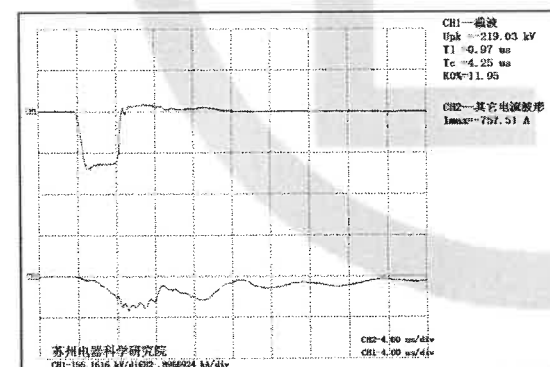
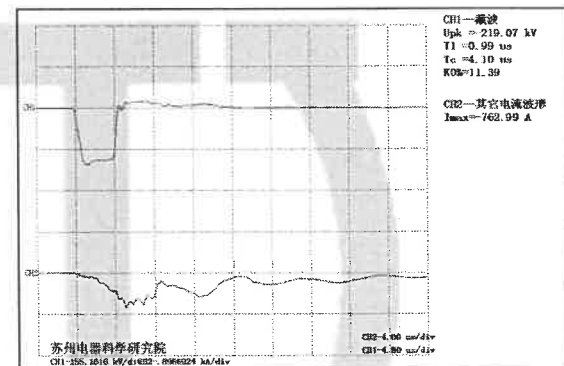
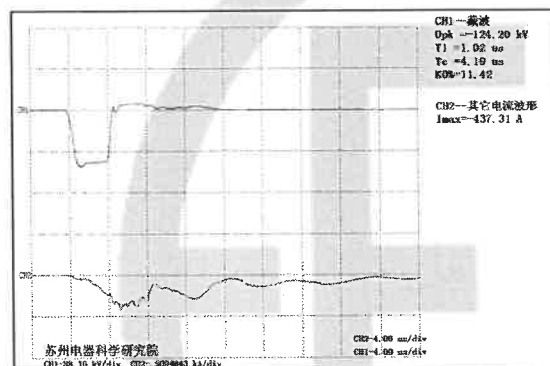
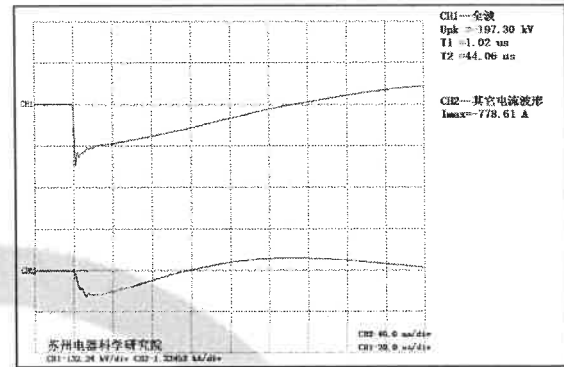
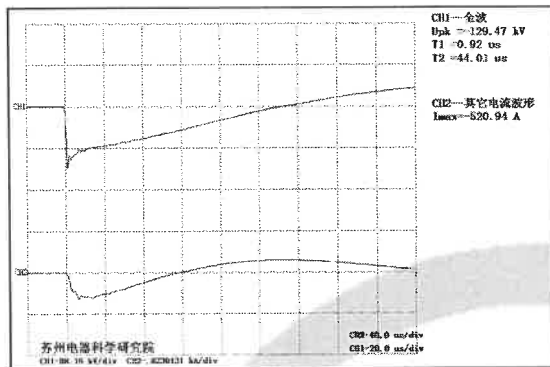
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Tested terminal: a Test polarity: negative Channel 1: voltage wave Channel 2: current wave



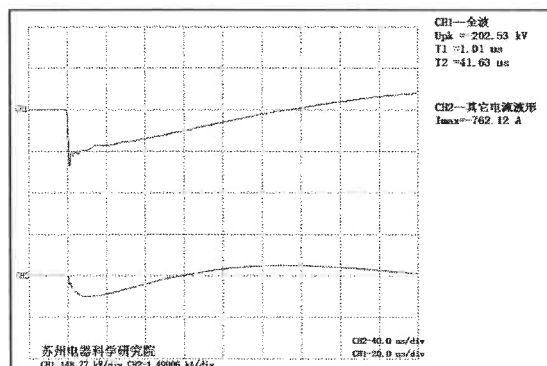
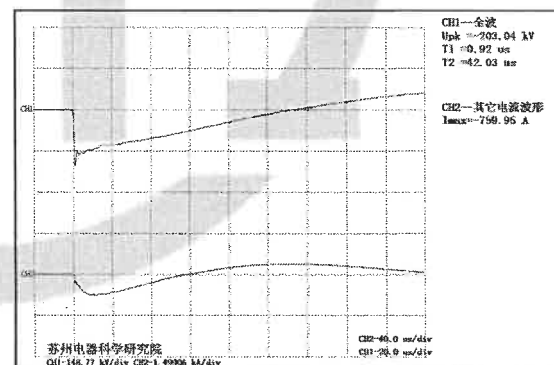
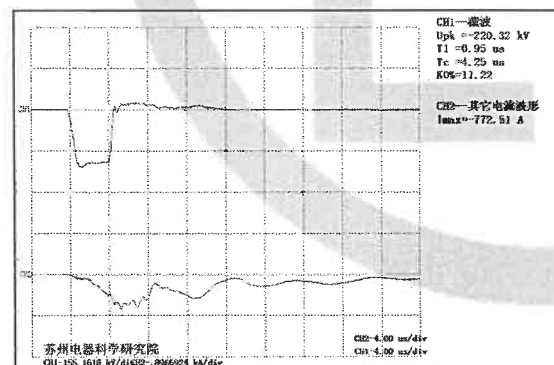
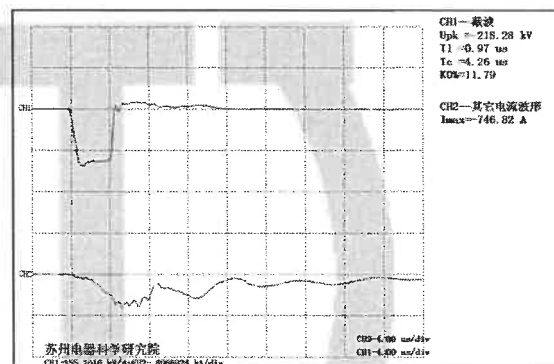
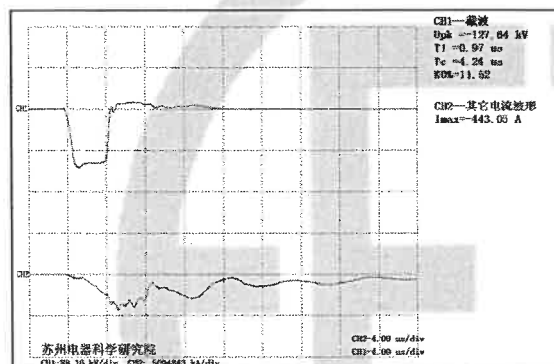
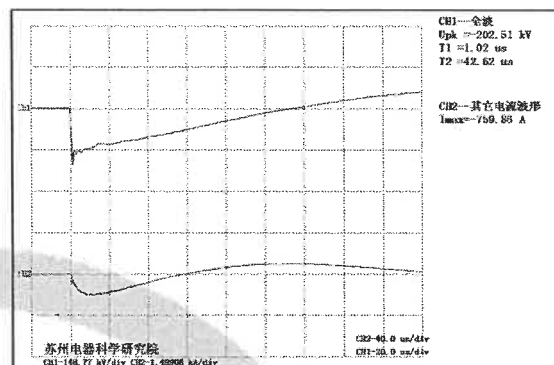
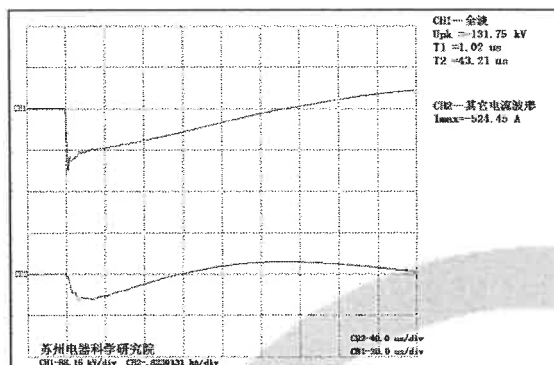
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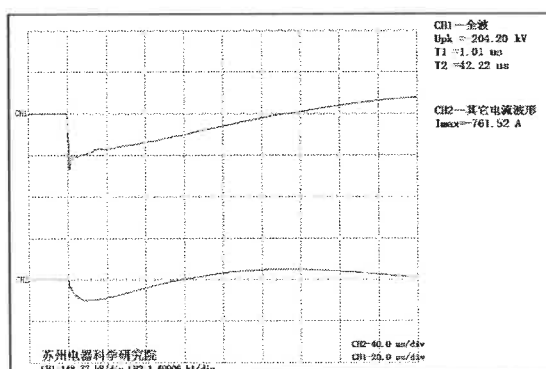
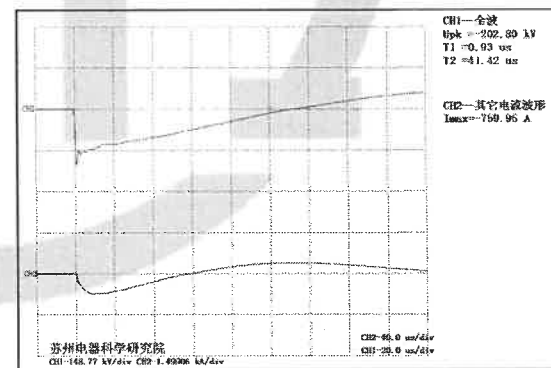
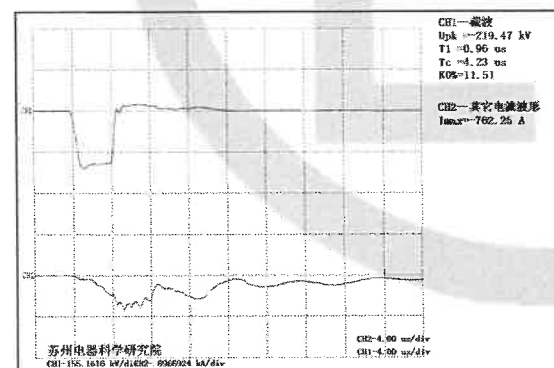
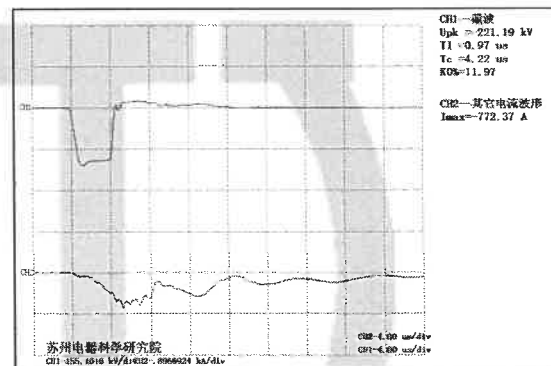
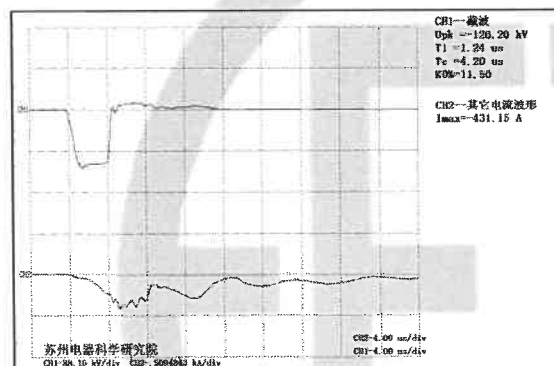
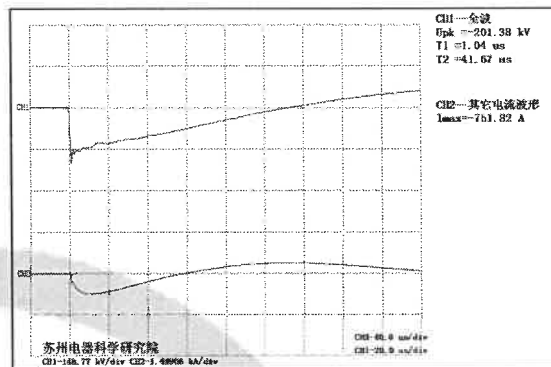
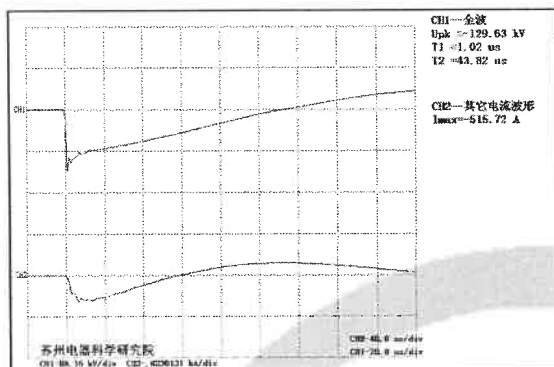
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Tested terminal: b Test polarity: negative Channel 1: voltage wave Channel 2: current wave



Tested terminal: c Test polarity: negative Channel 1: voltage wave Channel 2: current wave

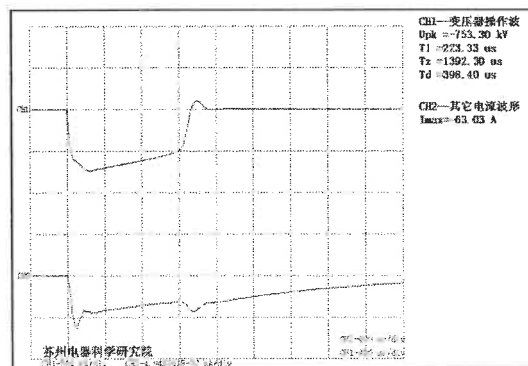
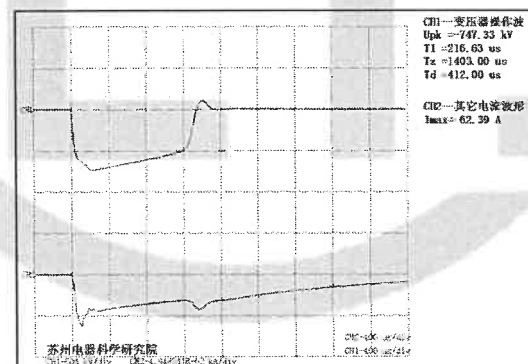
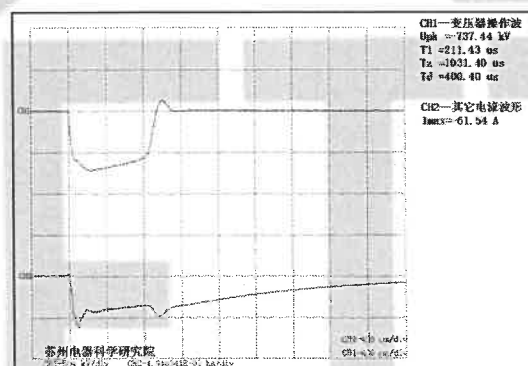
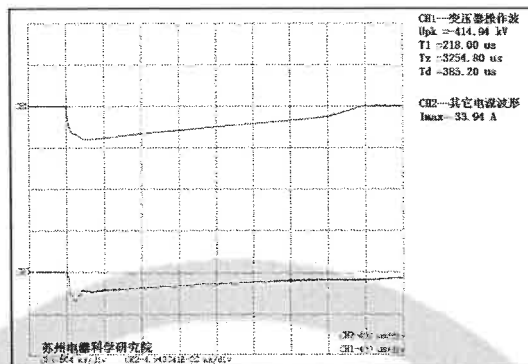


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4.21.4.15 Switching impulse test (SI) (routine test) Test date: Mar. 22, 2021 Atmospheric conditions of test: Relative humidity: 29%; Ambient temperature: 13.4℃; Oil temperature: 14.3℃; Air pressure: 101kPa.		
Test items and voltage		
Withstand terminals	Rated withstand voltage (kV)	Tapping position
A, B, C	750	1
Test sequence: Line terminal One reduced voltage switching impulse test; Three rated voltage switching impulse test; Test records: T1: wave front time; Td: peak value; Tz: duration of over zero; Upk: peak voltage . For waveform diagram, see P ₇₄ ~P ₇₆ . Voltage ranges of oscillograms are as below:		
Withstand terminals	Switching wave	
A, B, C	737.44~753.30	

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Tested terminal: A Test polarity: negative Channel 1: voltage wave Channel 2: current wave



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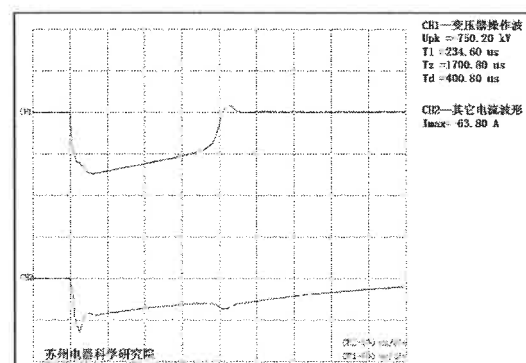
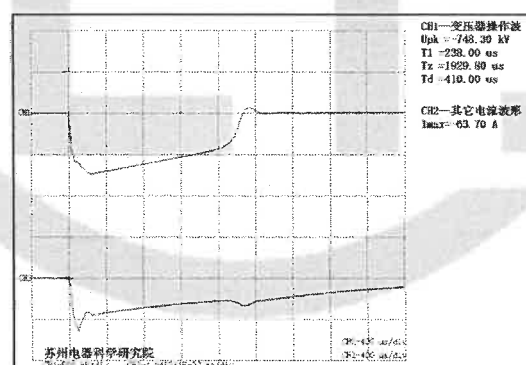
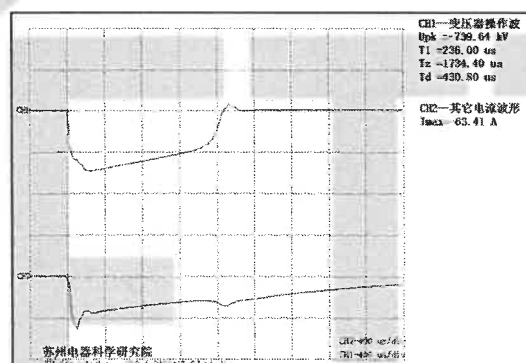
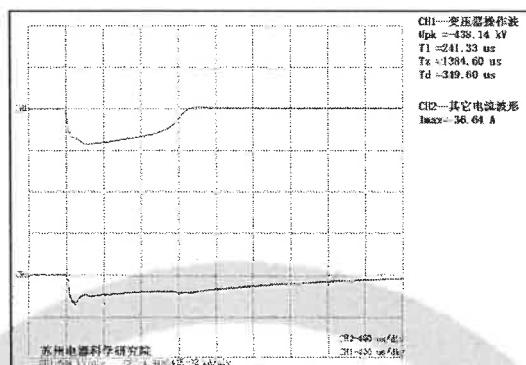
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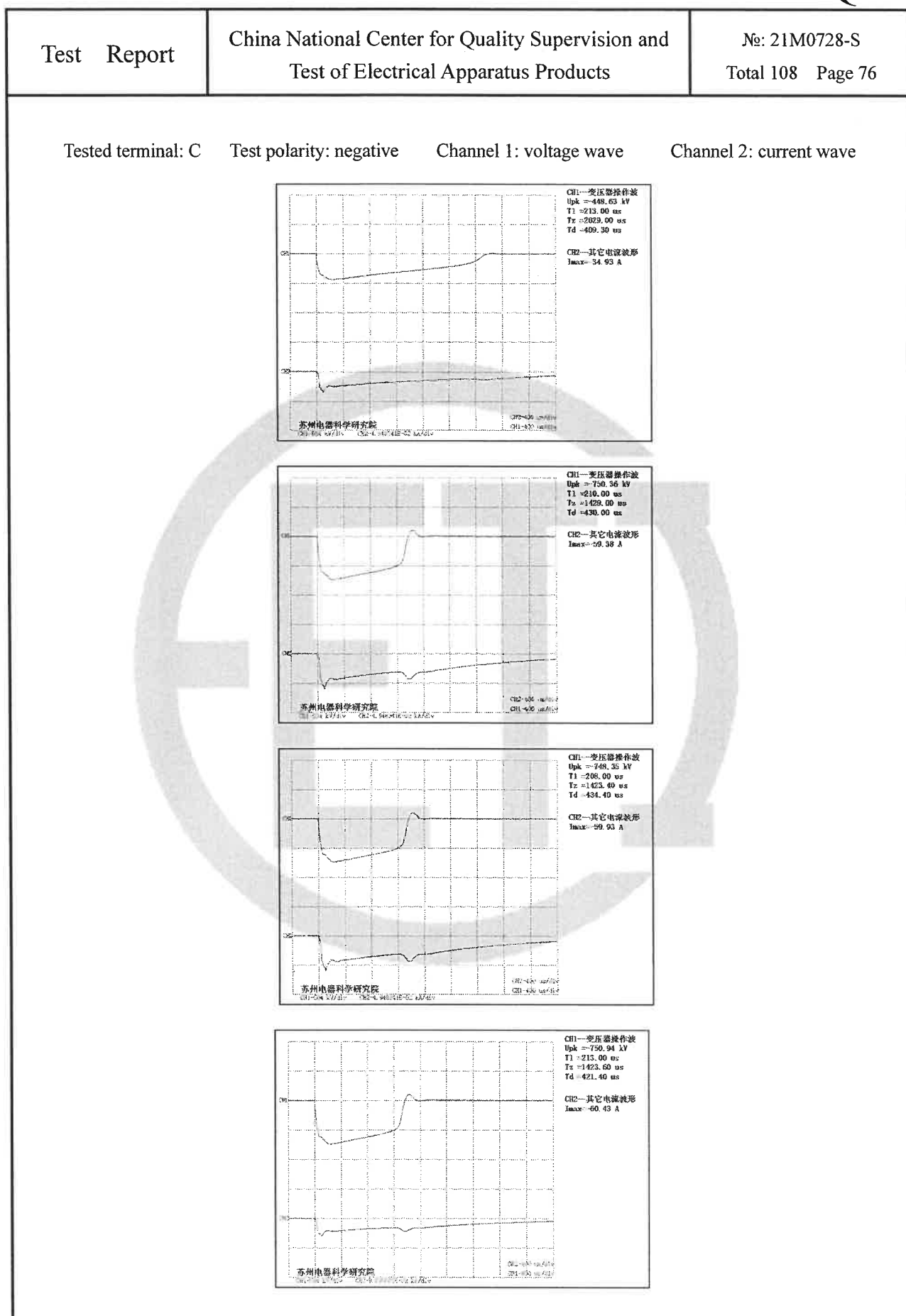
Tested terminal: B

Test polarity: negative

Channel 1: voltage wave

Channel 2: current wave

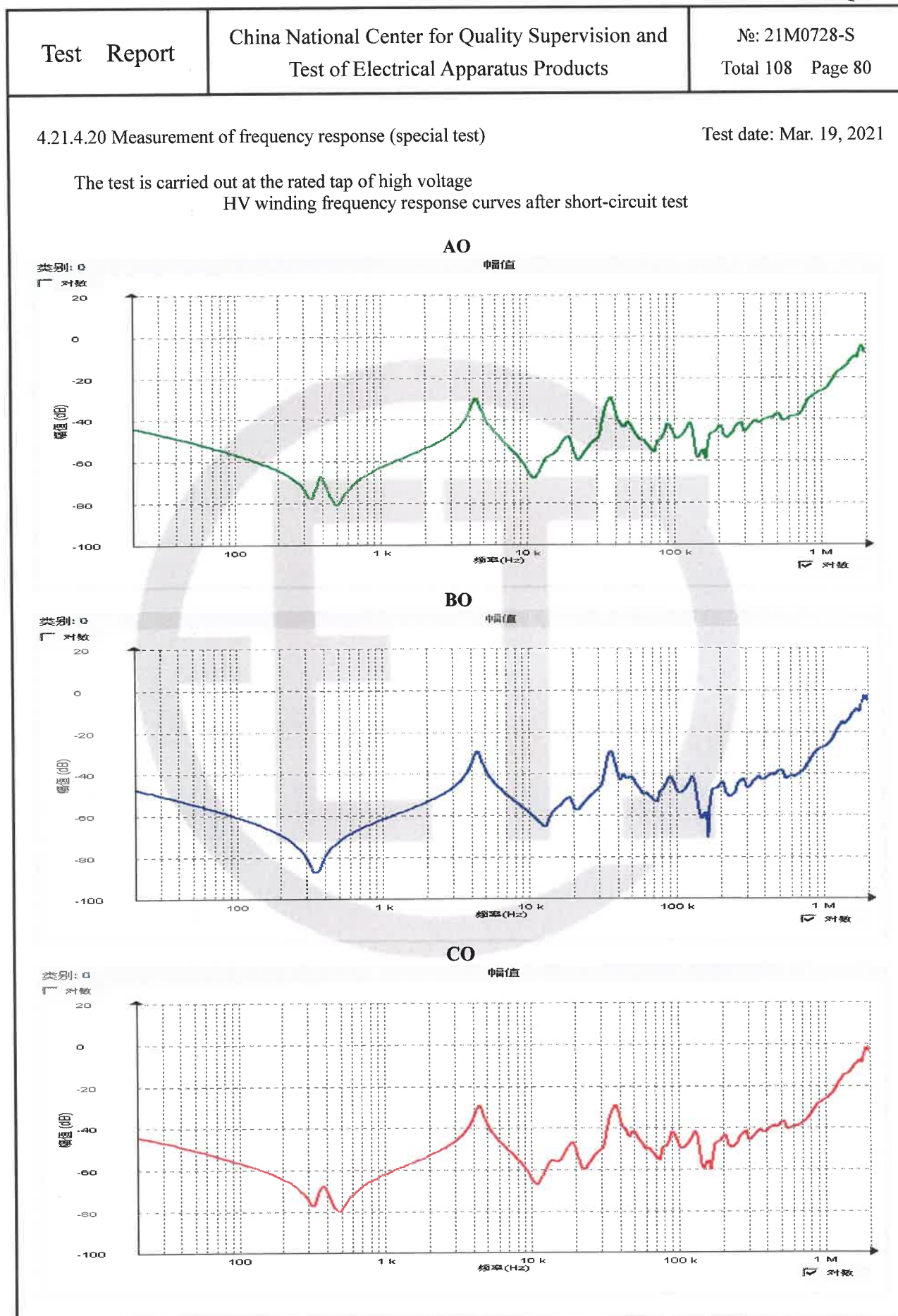


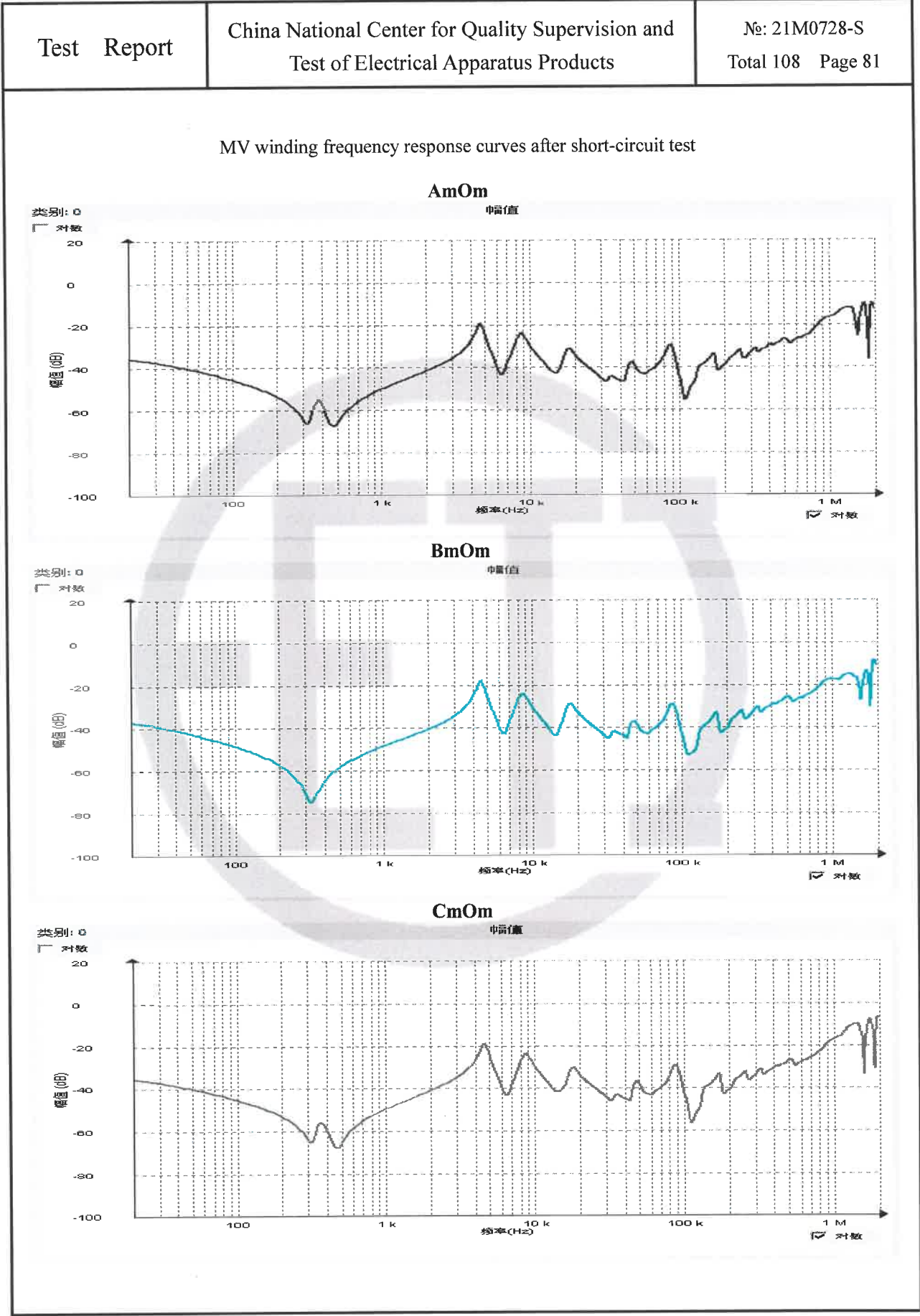


Test Report	China National Center for Quality Supervision and Test of Electrical Apparatus Products					№: 21M0728-S Total 108 Page 77			
4.21.4.16 Separate-source AC withstand voltage test (AV) (routine test)							Test date: Mar. 23, 2021		
Relative humidity: 40%; Ambient temperature: 12.7℃; Oil temperature: 13.5℃; Air pressure: 102kPa									
Parts of applied voltage			Test voltage (kV)			Test duration (s)		Result	
HV neutral point—MV, LV and earth			200			60		PASS	
MV neutral point—HV, LV and earth			140			60			
LV—HV, MV and earth			85			60			
4.21.4.17 Line terminal AC withstand test (LTAC) (special test)							Test date: Mar. 23, 2021		
Relative humidity: 37%; Ambient temperature: 13.3℃; Oil temperature: 13.7℃; Air pressure: 102kPa									
Phase to earth test									
Parts of applied voltage	Tapping position	Applied voltage (kV)	Induced voltage (kV)				Frequency (Hz)	Test duration (s)	Result
		LV	HV		MV				
a-c	2	73.5	A	395.0	Am	200.0	200	30	PASS
a-b		73.5	B	395.0	Bm	200.0			
b-c		73.5	C	395.0	Cm	200.0			

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4.21.4.18 Induced AC withstand voltage test with partial discharge measurement (IVPD) (routine test)								
Test date: Mar. 23, 2021								
Relative humidity: 37%; Ambient temperature: 13.3℃; Oil temperature: 13.7℃; Air pressure: 102kPa								
HV tapping position is 9b, frequency is 200Hz.								
Applied voltage		Duration (min)	Partial discharge magnitude (pC)					
Multiple	Phase to phase voltage (kV)		A	B	C	Am	Bm	Cm
$0.4U_r/\sqrt{3}$	50.8	/	<10	<5	<6	<8	<10	<9
$1.2U_r/\sqrt{3}$	152.4	1	<35	<29	<27	<32	<39	<32
$1.58U_r/\sqrt{3}$	200.7	5	<60	<47	<42	<45	<50	<48
$1.8U_r/\sqrt{3}$	228.6	0.5	/	/	/	/	/	/
$1.58U_r/\sqrt{3}$	200.7	5	<70	<70	<70	<60	<60	<60
		10	<70	<70	<70	<60	<60	<60
		15	<60	<60	<60	<60	<60	<60
		20	<60	<60	<60	<60	<60	<60
		25	<60	<60	<60	<60	<60	<60
		30	<60	<60	<60	<60	<60	<60
		35	<60	<60	<60	<60	<60	<60
		40	<60	<60	<60	<60	<60	<60
		45	<60	<60	<60	<60	<60	<60
		50	<60	<60	<60	<60	<60	<60
		55	<60	<60	<60	<60	<60	<60
		60	<60	<60	<60	<60	<60	<60
$1.2U_r/\sqrt{3}$	152.4	1	<30	<30	<30	<30	<30	<30
$0.4U_r/\sqrt{3}$	50.8	/	<10	<10	<10	<10	<10	<10
Remarks: Ur=220kV.								

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4.21.4.19 Insulating liquid test, measurement of dissolved gasses in dielectric liquid from each separate oil compartment except diverter switch compartment (routine test)							
Test date: Mar. 21, 2021 Relative humidity: 47%; Ambient temperature: 17.9°C							
Dielectric dissipation factor(90°C)	Breakdown voltage (kV)		Water content (mg/L)				
0.05%	62.1		6.1				
Gas chromatograph analysis (after short-circuit test, before dielectric retest) Test date: Mar. 21, 2021 μL/L							
H ₂	CO	CO ₂	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₂ H ₂	Total hydrocarbon
0	17.37	109.23	0.15	0	0	0	0.15
Gas chromatograph analysis (after dielectric retest, before long-duration no-load test) Test date: Mar. 23, 2021 μL/L							
H ₂	CO	CO ₂	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₂ H ₂	Total hydrocarbon
0	20.26	123.14	0.17	0	0	0	0.17
Gas chromatograph analysis (after long-duration no-load test, before temperature-rise test) Test date: Mar. 24, 2021 μL/L							
H ₂	CO	CO ₂	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₂ H ₂	Total hydrocarbon
0	22.45	132.46	0.19	0	0	0	0.19
Gas chromatograph analysis (after all tests) Test date: Mar. 27, 2021 μL/L							
H ₂	CO	CO ₂	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₂ H ₂	Total hydrocarbon
0	25.43	147.26	0.21	0	0	0	0.21

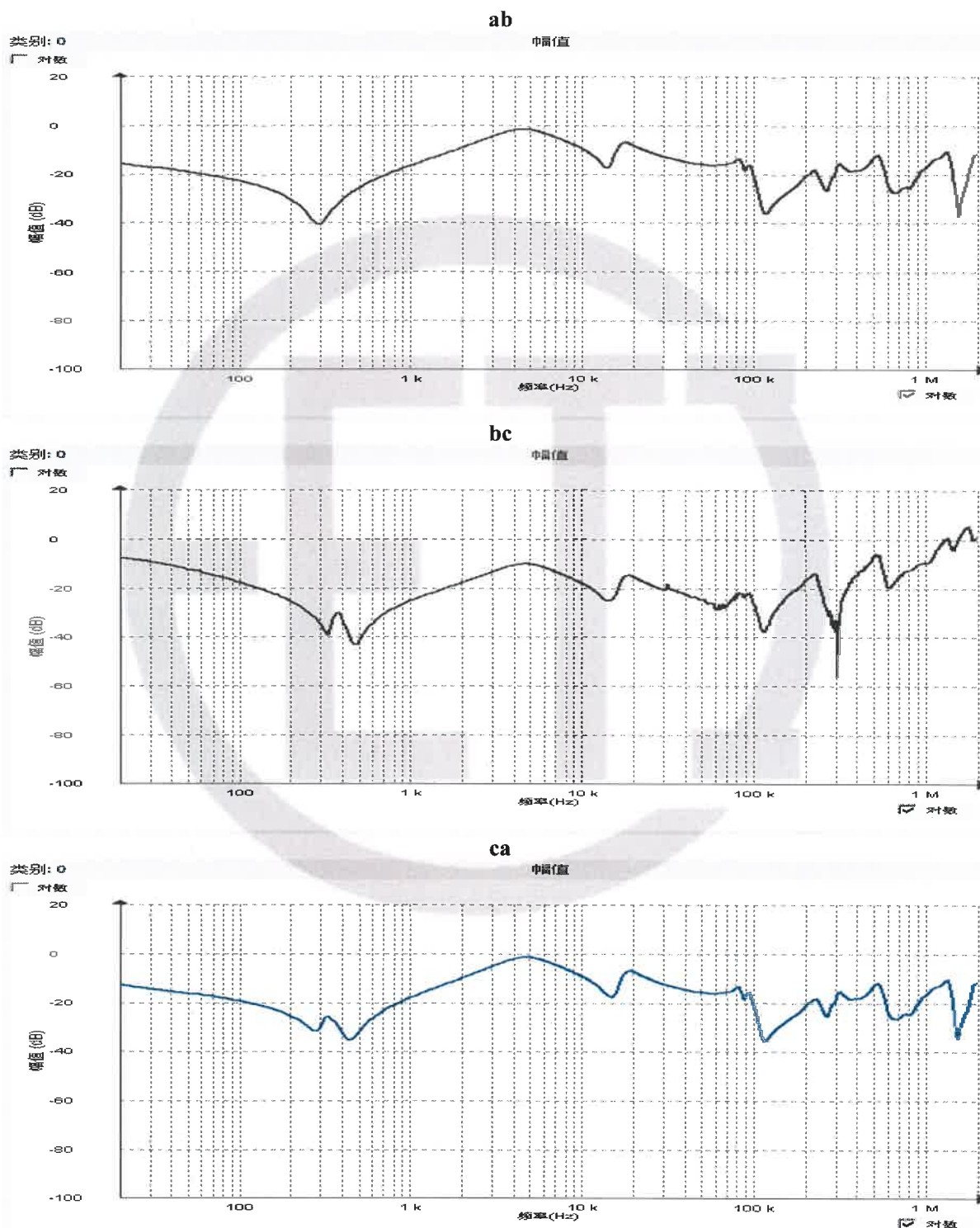




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LV winding frequency response curves after short-circuit test



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4.22 Measurement of no-load excitation characteristics (commission test)			Test date: Mar. 13, 2021
Voltage	Effective voltage (kV)	Average voltage (kV)	Current (A)
0.1U _r	3.857	3.852	0.423
0.2U _r	7.712	7.701	0.559
0.3U _r	11.553	11.549	0.662
0.4U _r	15.410	15.405	0.747
0.5U _r	19.258	19.255	0.875
0.6U _r	23.110	23.109	0.932
0.7U _r	26.949	26.944	1.158
0.8U _r	30.811	30.801	1.366
0.9U _r	34.661	34.646	1.755
0.95U _r	36.571	36.578	2.122
1.0U _r	38.521	38.513	3.557
1.05U _r	40.424	40.422	5.524
1.1U _r	42.353	42.356	8.346

Remarks: U_r=38.5kV.

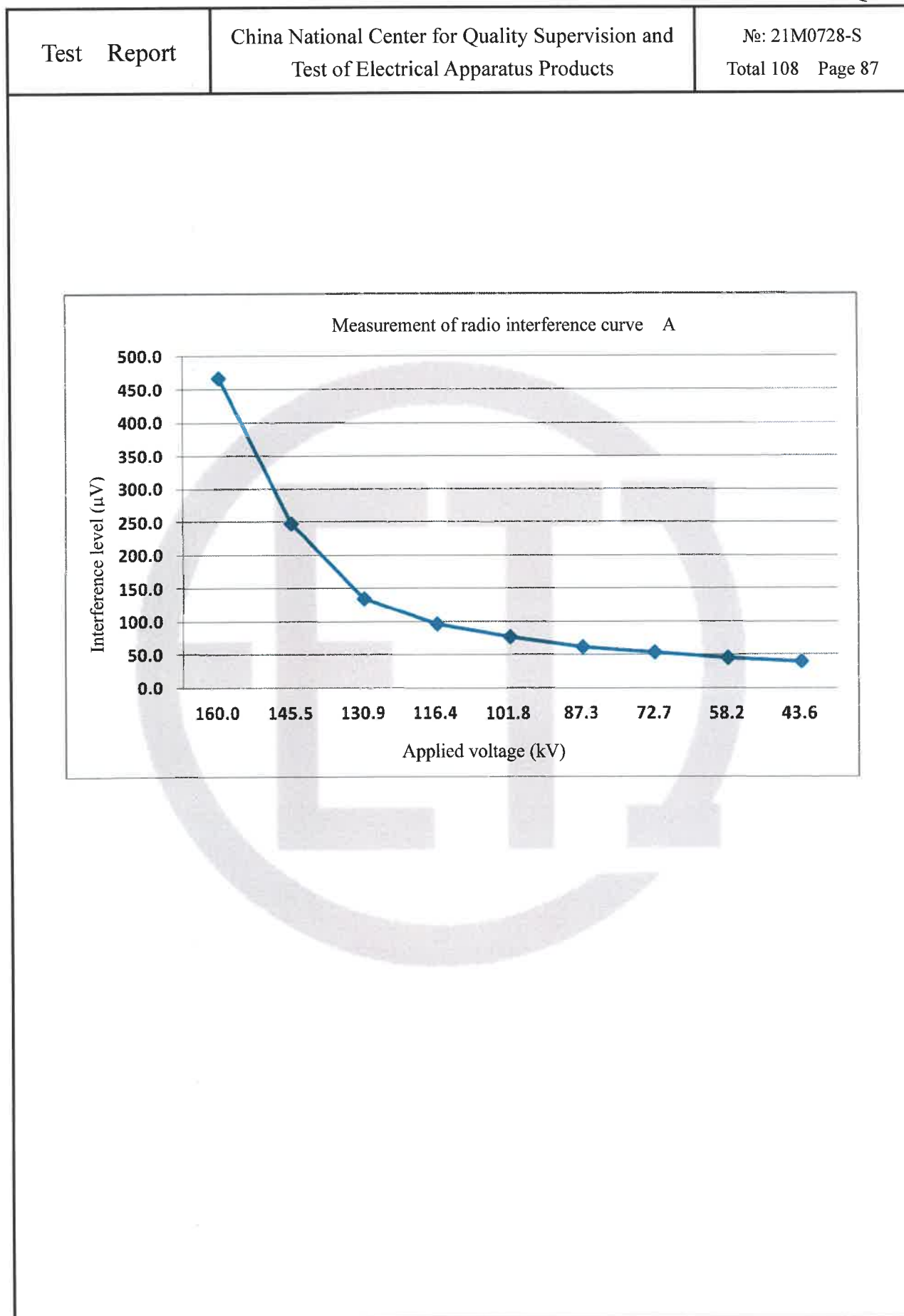
No-load excitation characteristic curve

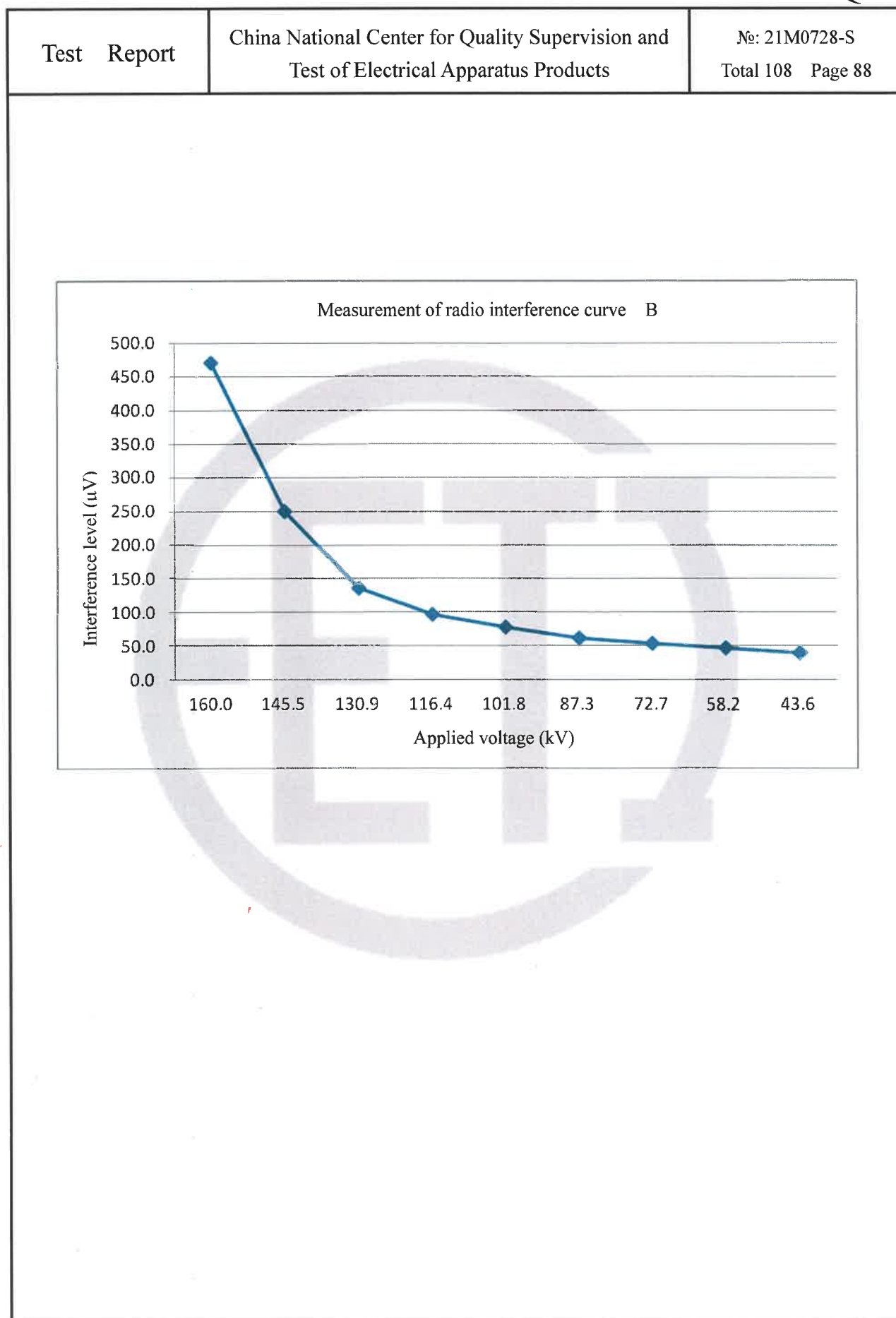
Voltage (kV)	Current (A)
3.857	0.423
7.712	0.559
11.553	0.662
15.410	0.747
19.258	0.875
23.110	0.932
26.949	1.158
30.811	1.366
34.661	1.755
36.571	2.122
38.521	3.557
40.424	5.524
42.353	8.346

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4.23 Long-duration no-load test (special test)				Test date: from Mar. 23, 2021 to Mar. 24, 2021		
Test with 1.1 times rated voltage applied on LV side for 12h. No C ₂ H ₂ is found in oil and the content of total hydrocarbon has no obvious variation before and after the test. For gas chromatograph analysis data, see 4.21.4.19.						
Duration (h)	Voltage (kV)		Current (A)	No-load loss (kW)		
	Effective value	Average value				
1	42.437	42.412	17.628	122.812		
2	42.562	42.515	17.636	122.315		
3	42.968	42.863	17.647	123.256		
4	42.637	42.542	17.528	122.364		
5	42.774	42.739	17.645	122.939		
6	42.693	42.656	17.843	122.826		
7	42.996	42.554	17.845	122.733		
8	42.988	42.799	17.937	122.735		
9	42.369	42.949	17.732	122.157		
10	42.453	42.241	17.694	122.371		
11	42.431	42.211	17.736	122.159		
12	42.647	42.592	17.063	122.963		
4.24 Measurement of zero-sequence impedances on three-phase transformers (special test)						
Test date: Mar. 12, 2021						
Connection symbol	Power supply terminal	Open-circuit terminal	Short-circuit terminal	Applied current (A)	Measured voltage (V)	Impedance (Ω)
YNyn0d11	ABC-O	a, b, c, Am, Bm, Cm, Om	/	231.7	4132.2	53.50
		a, b, c	Am, Bm, Cm, Om	241.7	2465.2	30.67
	Am, Bm, Cm—Om	a, b, c, A, B, C, O	/	386.3	619.7	4.813
		a, b, c	A, B, C, O	392.7	355.8	2.718

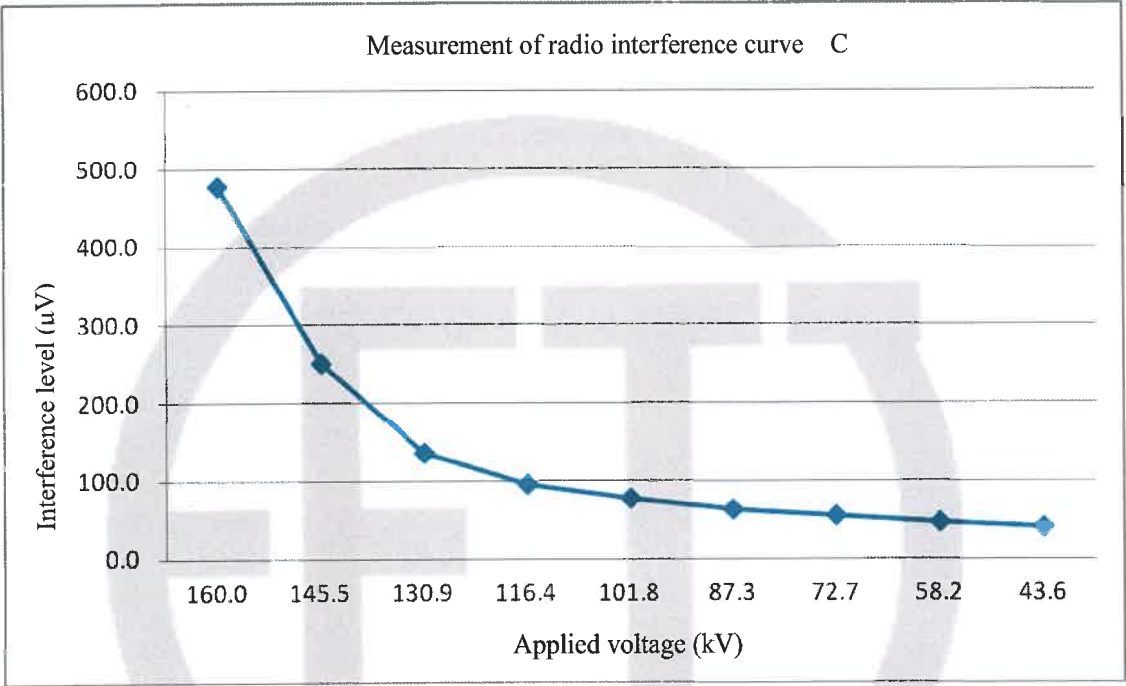
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4.25 Measurement of the harmonics of the no-load current (commission test)					Test date: Mar. 22, 2021	
No	CH-A THD =22.18		CH-B THD =27.89		CH-C THD =25.49	
	In(A)	In/I1(%)	In(A)	In/I1(%)	In(A)	In/I1(%)
01	4.288	100.00	3.111	100.00	3.275	100.00
02	0.02	0.53	0.04	1.35	0.02	0.66
03	0.11	2.54	0.21	6.74	0.18	5.44
04	0.06	1.47	0.08	2.47	0.08	2.47
05	0.90	21.08	0.80	25.80	0.77	23.60
06	0.15	3.46	0.10	3.15	0.10	2.92
07	0.18	4.17	0.12	3.95	0.19	5.67
08	0.05	1.05	0.03	0.84	0.02	0.71
09	0.03	0.73	0.05	1.63	0.03	0.83
10	0.01	0.13	0.02	0.56	0.01	0.40
11	0.09	2.04	0.10	3.06	0.07	2.27
12	0.04	1.02	0.06	1.93	0.06	1.98
13	0.05	1.07	0.06	1.95	0.04	1.16
14	0.03	0.60	0.08	2.47	0.05	1.54
15	0.02	0.57	0.04	1.16	0.03	0.89
16	0.02	0.55	0.06	2.07	0.03	0.83
17	0.02	0.47	0.02	0.49	0.02	0.47
18	0.00	0.07	0.02	0.63	0.01	0.33
19	0.01	0.14	0.01	0.47	0.00	0.05

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4.26 Measurement of radio interference (commission test)				Test date: Mar. 23, 2021		
Atmospheric conditions of test: Relative humidity:30%; Ambient temperature: 13.7°C; Air pressure: 102kPa.						
Background: 3.4(μV); Test frequency: 1(MHz); B ₁ (dB)=20.1; B ₂ (dB)=23.6;						
Circuit attenuation coefficient Bc=B ₂ -B ₁ =3.5(dB);						
Resistance network attenuation coefficient $B_R = 20\log \frac{300}{R^{1/2}} = 21.58$.						
No	Test voltage (kV)			Measured interference level (μV)		
	Required values (kV)	Measured values (kV)	Duration (min)	A	B	C
1	$1.1 \times U_m / \sqrt{3}$	160.0	5	472.1	473.0	472.6
2	$0.3 \times U_m / \sqrt{3}$	43.6	Decreased by steps	41.1	39.8	40.2
3	$1.1 \times U_m / \sqrt{3}$	160.0	1	466.7	472.1	477.5
4	$1.0 \times U_m / \sqrt{3}$	145.5	Decreased by steps	247.7	250.6	250.6
5	$0.9 \times U_m / \sqrt{3}$	130.9		134.6	136.1	136.1
6	$0.8 \times U_m / \sqrt{3}$	116.4		96.4	97.5	96.4
7	$0.7 \times U_m / \sqrt{3}$	101.8		76.6	77.4	77.4
8	$0.6 \times U_m / \sqrt{3}$	87.3		61.5	62.2	63.0
9	$0.5 \times U_m / \sqrt{3}$	72.7		53.6	54.2	54.8
10	$0.4 \times U_m / \sqrt{3}$	58.2		46.1	46.7	47.2
11	$0.3 \times U_m / \sqrt{3}$	43.6		39.7	40.2	40.6
See the diagram of curves on P ₈₇₋₈₉ .						





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Test Report	China National Center for Quality Supervision and Test of Electrical Apparatus Products						№: 21M0728-S Total 108 Page 90																																																																													
4.27 Temperature-rise test (including calculation of the winding hot-spot temperature-rise) (type test) Test date: Mar. 24, 2021 The method of temperature rise is the equivalent test in short-circuit connection. The tapping position is 17, Test duration is 11h and of which the stabilization time is 3h. Measurement of top oil temperature rise: HV is supplying power. MV is connected by short-circuit, it is required to apply 855.984kW of total loss and 855.687kW is actually applied during testing. Measurement of HV and MV windings temperature-rise: test duration is 1h, 699.82A current is required and 700.56A is actually applied on HV side during testing. Measurement of LV winding temperature-rise: the HV supplies power, LV is short-circuited, test duration is 1h. 349.91A current is required and 351.46A is actually applied on HV side during testing. Measured data <table border="1"> <tr> <th colspan="4">Top oil temperature-rise and average oil temperature-rise</th> <th colspan="6">Measurement of average temperature-rise windings to oil</th> <th colspan="2">Ambient temperature (°C)</th> </tr> <tr> <th>Top oil temperature (°C)</th> <th>Average oil temperature (°C)</th> <th>Total loss injection/specified total loss (%)</th> <th>Current injection/rated current (%)</th> <th colspan="2">Cold resistance (Ω)</th> <th colspan="2">Average oil temperature (°C)</th> <th colspan="2">Average winding temperature (°C)</th> <th>Total loss</th> <th>Measurement of cold resistance</th> </tr> <tr> <td rowspan="2">63.9</td> <td rowspan="2">48.9</td> <td rowspan="2">99.96</td> <td rowspan="2">100.10</td> <td>HV</td> <td>0.3911</td> <td>At the instant of power off</td> <td>48.4</td> <td>HV</td> <td>69.3</td> <td rowspan="4">16.4</td> <td rowspan="4">15.1</td> </tr> <tr> <td>MV</td> <td>0.07862</td> <td>At the end of cooling curve</td> <td>45.8</td> <td>MV</td> <td>70.2</td> </tr> <tr> <td rowspan="2">/</td> <td rowspan="2">/</td> <td rowspan="2">/</td> <td rowspan="2">100.44</td> <td rowspan="2">LV</td> <td rowspan="2">12.32 × 10⁻³</td> <td>At the instant of power off</td> <td>41.5</td> <td rowspan="2">LV</td> <td rowspan="2">65.5</td> </tr> <tr> <td>At the end of cooling curve</td> <td>40.3</td> </tr> </table> Calculations of temperature-rise <table border="1"> <tr> <td>Top oil temperature-rise (K)</td> <td colspan="2">47.5</td> </tr> <tr> <td rowspan="3">Winding temperature-rise (K)</td> <td>HV</td> <td>53.3</td> </tr> <tr> <td>MV</td> <td>54.2</td> </tr> <tr> <td>LV</td> <td>56.3</td> </tr> <tr> <td rowspan="3">Winding hot-spot temperature-rise (K)</td> <td>HV</td> <td>72.5</td> </tr> <tr> <td>MV</td> <td>73.6</td> </tr> <tr> <td>LV</td> <td>76.1</td> </tr> <tr> <td>Structural parts highest hot-spot temperature-rise of tank (K)</td> <td colspan="2">61.0</td> </tr> </table> Remarks: the calculated of temperature-rise are the corrected value under specified total loss and rated current, winding hot-spot factor is 1.2.											Top oil temperature-rise and average oil temperature-rise				Measurement of average temperature-rise windings to oil						Ambient temperature (°C)		Top oil temperature (°C)	Average oil temperature (°C)	Total loss injection/specified total loss (%)	Current injection/rated current (%)	Cold resistance (Ω)		Average oil temperature (°C)		Average winding temperature (°C)		Total loss	Measurement of cold resistance	63.9	48.9	99.96	100.10	HV	0.3911	At the instant of power off	48.4	HV	69.3	16.4	15.1	MV	0.07862	At the end of cooling curve	45.8	MV	70.2	/	/	/	100.44	LV	12.32 × 10 ⁻³	At the instant of power off	41.5	LV	65.5	At the end of cooling curve	40.3	Top oil temperature-rise (K)	47.5		Winding temperature-rise (K)	HV	53.3	MV	54.2	LV	56.3	Winding hot-spot temperature-rise (K)	HV	72.5	MV	73.6	LV	76.1	Structural parts highest hot-spot temperature-rise of tank (K)	61.0	
Top oil temperature-rise and average oil temperature-rise				Measurement of average temperature-rise windings to oil						Ambient temperature (°C)																																																																										
Top oil temperature (°C)	Average oil temperature (°C)	Total loss injection/specified total loss (%)	Current injection/rated current (%)	Cold resistance (Ω)		Average oil temperature (°C)		Average winding temperature (°C)		Total loss	Measurement of cold resistance																																																																									
63.9	48.9	99.96	100.10	HV	0.3911	At the instant of power off	48.4	HV	69.3	16.4	15.1																																																																									
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	MV	73.6																																																																																		
	LV	76.1																																																																																		
Structural parts highest hot-spot temperature-rise of tank (K)	61.0																																																																																			

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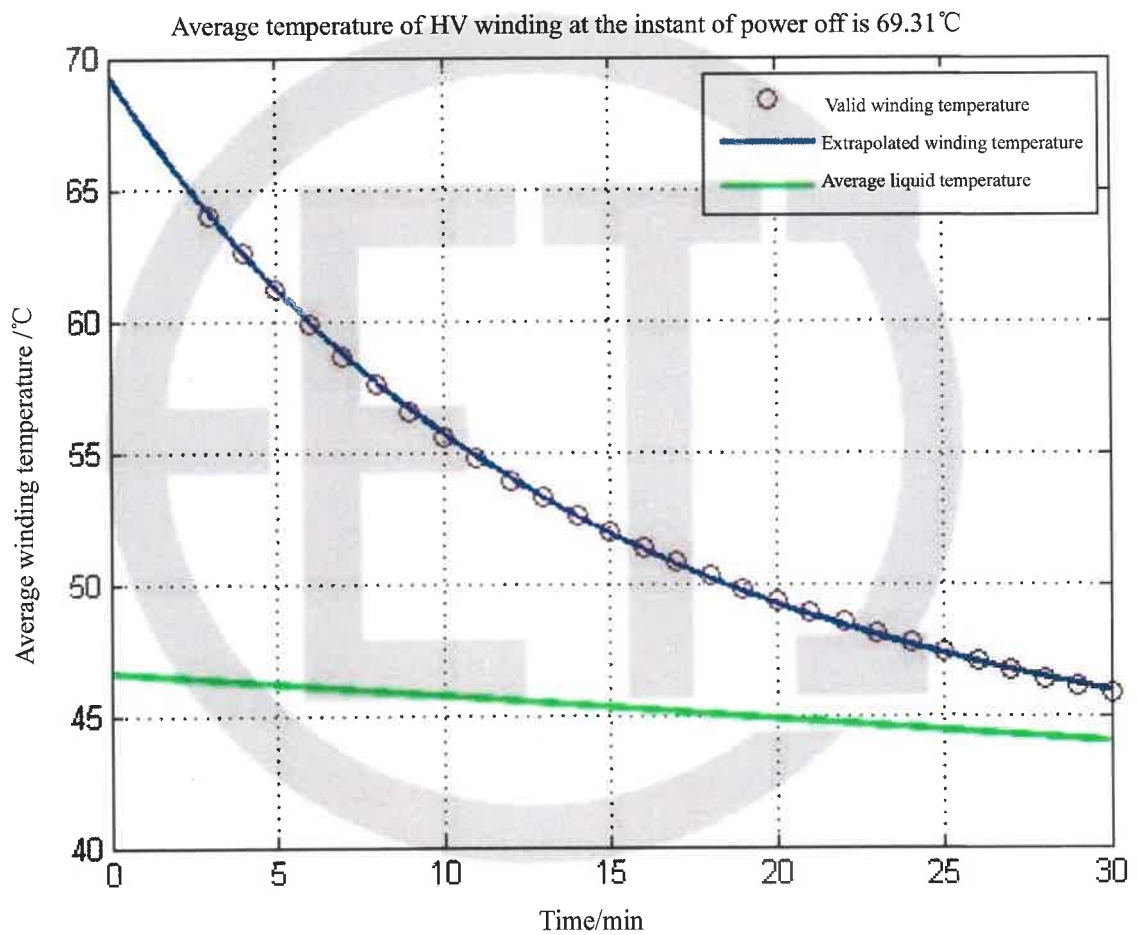
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Winding temperature curve

Average winding temperature data

Average HV winding
temperature

69.3℃



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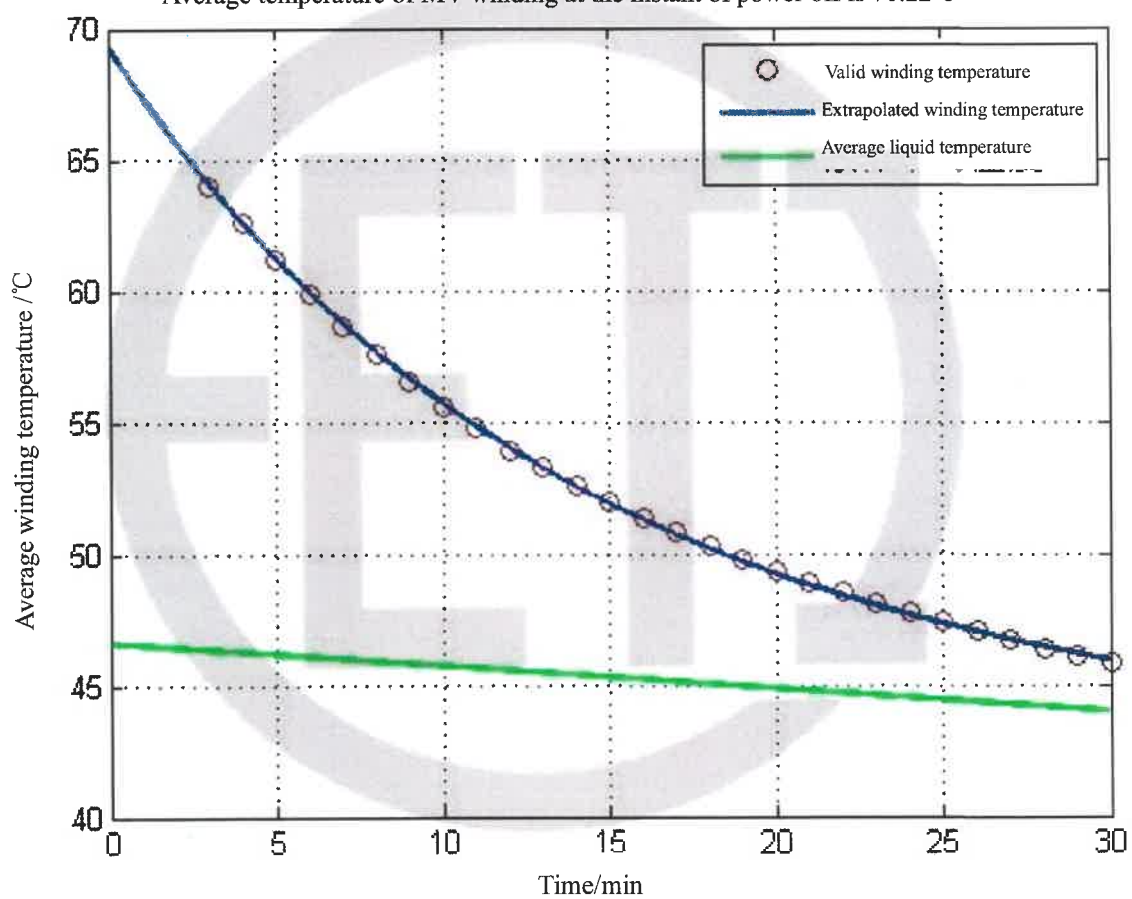
Winding temperature curve

Average winding temperature data

Average MV winding
temperature

70.2℃

Average temperature of MV winding at the instant of power off is 70.22℃



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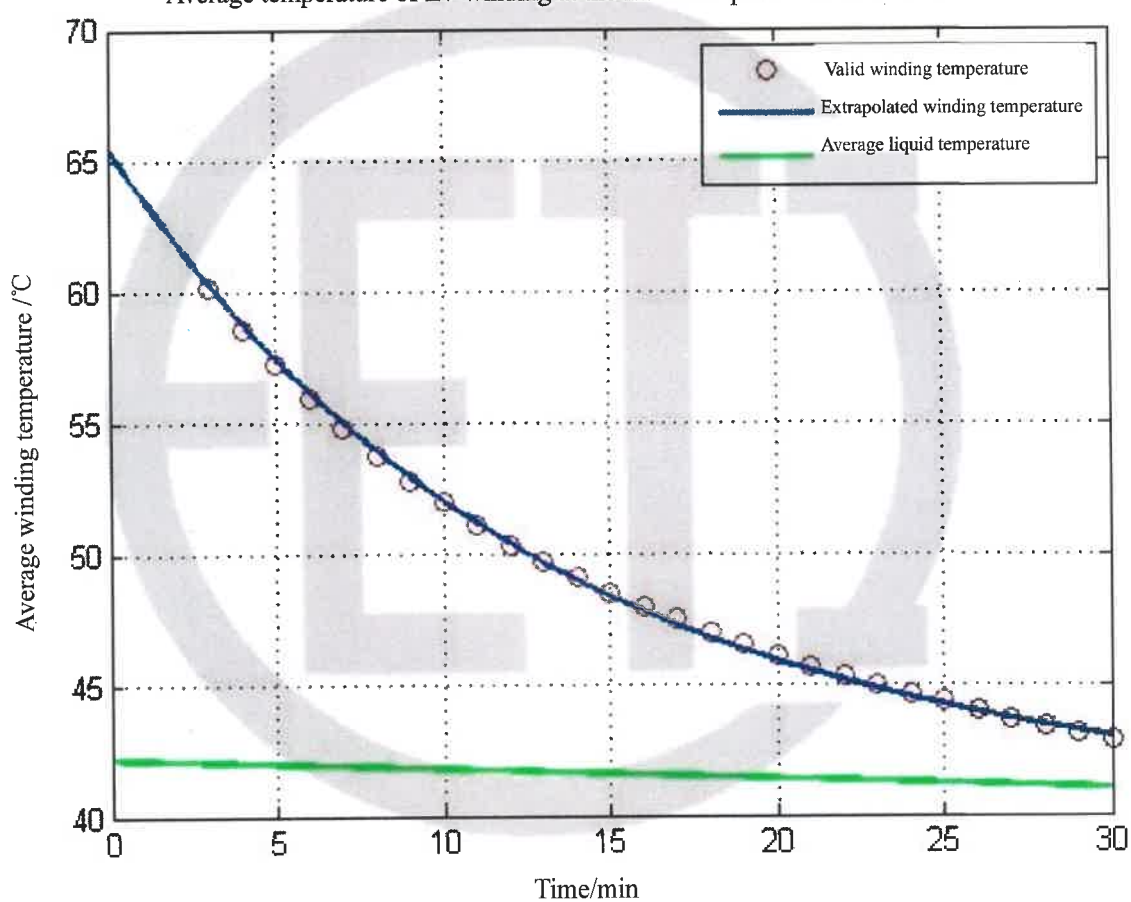
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Winding temperature curve

Average winding temperature data

Average LV winding temperature	65.5℃
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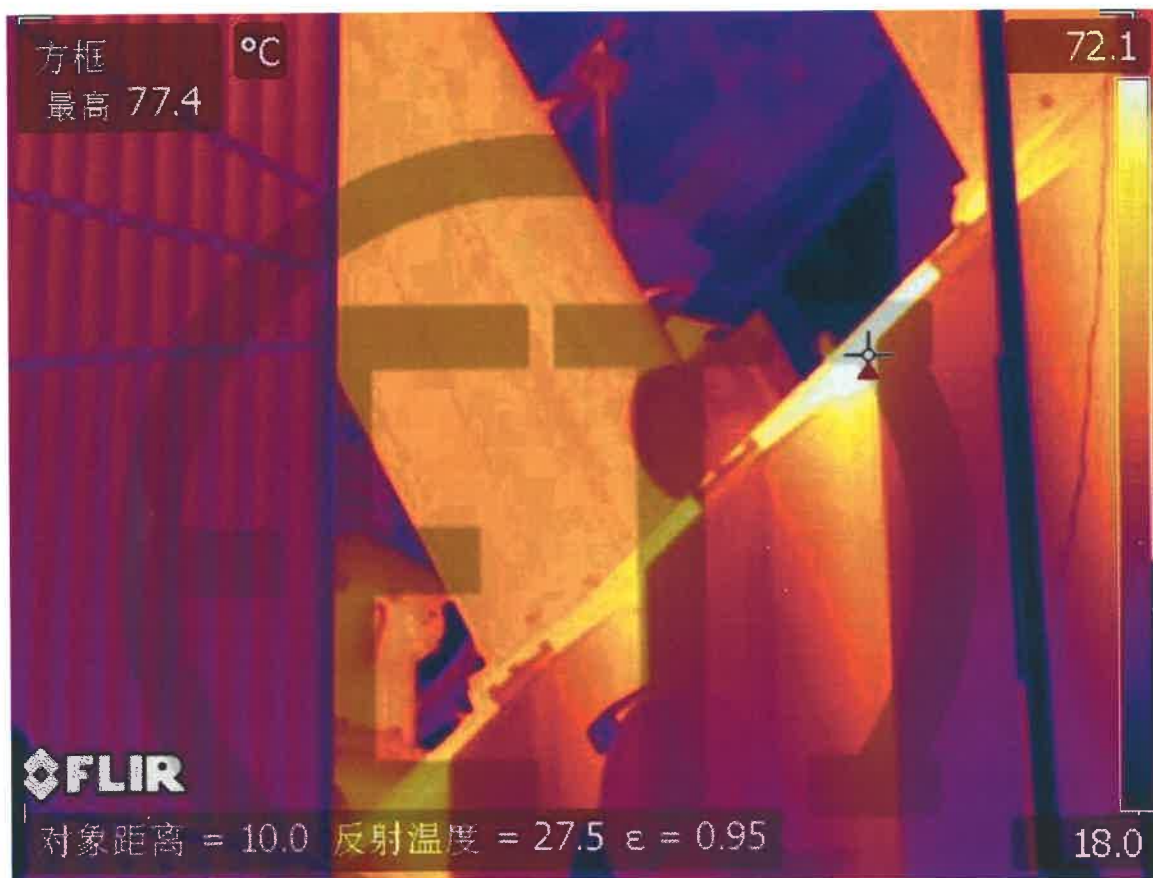
Average temperature of LV winding at the instant of power off is 65.47℃



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Thermograph of tank surface and structural parts temperature-rise



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4.28 Leak testing with pressure for liquid-immersed transformers (routine test) Test date: from Mar. 25, 2021 to Mar. 27, 2021					
Test method	Parts of applied voltage	Applied pressure (kPa)	Residual pressure (kPa)	Duration (h)	Result
Static pressure method	Body	30.0	24	29.5	No oil leakage or damage
	On-load tap-changer tank	30.0	24	29.6	No oil leakage or damage
Remarks: the product is a general tank.					
					

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4.29 Determination of sound levels (type test) Test date: Mar. 24, 2021 4.29.1 Rough estimation of the load current sound power level Equation: $L_{WA,IN} \approx 39 + 18 \lg \frac{S_r}{S_p} = 81.8 \text{ dB(A)}$ where: S_r—the rated power is 240MVA; S_p—the reference power is 1MVA. Because $L_{WA,IN}$ is less 14.2dB (A) than limit value 96.0dB (A) of assured sound power level, according to standard requirement, it need not to measure load current sound level. 4.29.2 Measurement of sound pressure level and calculation of sound power level The transformer is rated excitation; the prescribed contour shall be spaced 0.3m away from the principal radiating surface, the distance between measured points is 0.97m, the number of measured points is 76, the height of measured point 1 is 1.27m and point 2 is 2.53m.						
Test environment						
The total area of the surface of the test room $S_v \text{ (m}^2\text{)}$	The average acoustic absorption coefficient α	The amount of acoustic absorption A $\text{(m}^2\text{)}$	Distance from the principal radiating surface (m)	The area of the measurement surface S $\text{(m}^2\text{)}$	Environmental correction K (dB)	
24650.0	0.15	3697.5	0.3	174.2	0.8	
Measured values (dB)						
Status of cooling device	Average of background noise		Average noise value of transformer $\overline{L_{pA0}}$	A weighted sound pressure level $\overline{L_{pA}} = 10 \lg(10^{0.1\overline{L_{pA0}}} - 10^{0.1\overline{L_{bgA}}}) - K$	A weighted sound power level $L_{WA} = \overline{L_{pA}} + 10 \lg(S/S_0)$	
	Before the test	After the test				
/	35.2	35.4	63.2	62	85	
Remarks: $\overline{L_{pA0}}$: the uncorrected average A-weighted sound pressure level; $\overline{L_{pA0}} = 10 \lg(\frac{1}{N} \sum_{i=1}^N 10^{0.1L_{pAi}})$ $\overline{L_{bgA}}$: the lower of the two calculated average A weighted background noise pressure level.						

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4.30 Mechanical strength test of tank (type test)										Test date: Mar. 25, 2021		
Test method		Applied pressure (kPa)							Duration (min)			
Positive pressure		100							5			
Degree of vacuum		0.133							5			
Measured point												
Measured items		Tank wall								Tank cover		
		HV side			LV side			Left side	Right side	Middle of length		
		Left	Middle	Right	Left	Middle	Right	Middle	Middle	Left	Middle	Right
Positive pressure	Initial distance (mm)	200	200	200	150	150	152	160	165	90	92	95
	Distance after pressure injection (mm)	195	195	194	144	144	145	152	160	87	89	92
	Distance without pressure (mm)	200	199	199	149	149	150	159	163	90	91	94
	Elastic deformation (mm)	5	5	6	6	6	7	8	5	3	3	3
	Permanent deformation (mm)	0	1	1	1	1	2	1	2	0	1	1
Degree of vacuum	Initial distance (mm)	210	210	215	180	180	180	80	90	95	95	92
	Distance after pressure injection (mm)	215	216	220	184	185	184	83	92	97	98	95
	Distance without pressure (mm)	210	215	218	180	184	181	80	90	95	96	93
	Elastic deformation (mm)	5	6	5	4	5	4	3	2	2	3	3
	Permanent deformation (mm)	0	5	3	0	4	1	0	0	0	1	1
Result		No damage										
Remarks: 1. the product is a general tank. 2. the described left and right sides of test point are viewed from HV side. 3. the left, middle and right test points of HV and LV side are obtained from the 1/2 height in vertical direction, 1/4, 1/2 and 3/4 position respectively in horizontal direction.												

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HV side before short-circuit:



LV side before short-circuit:

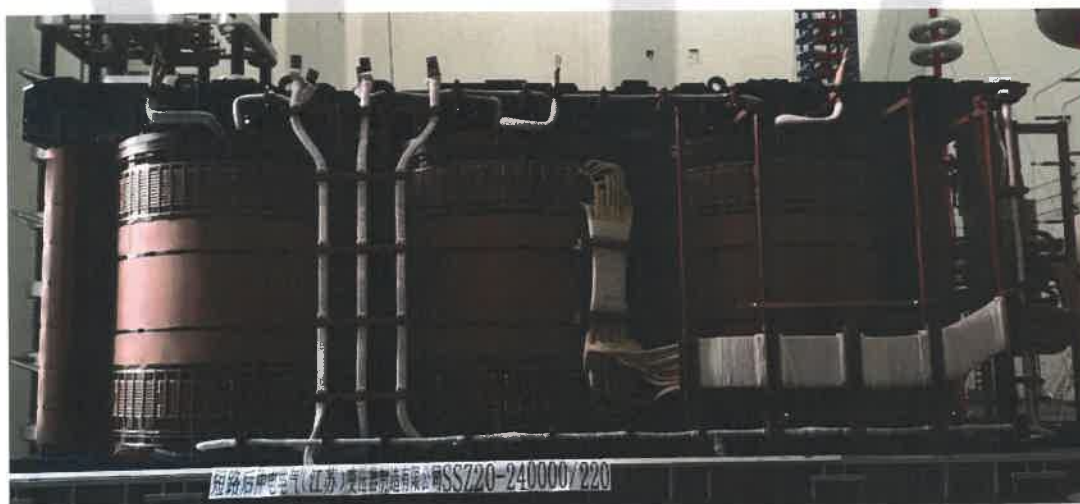


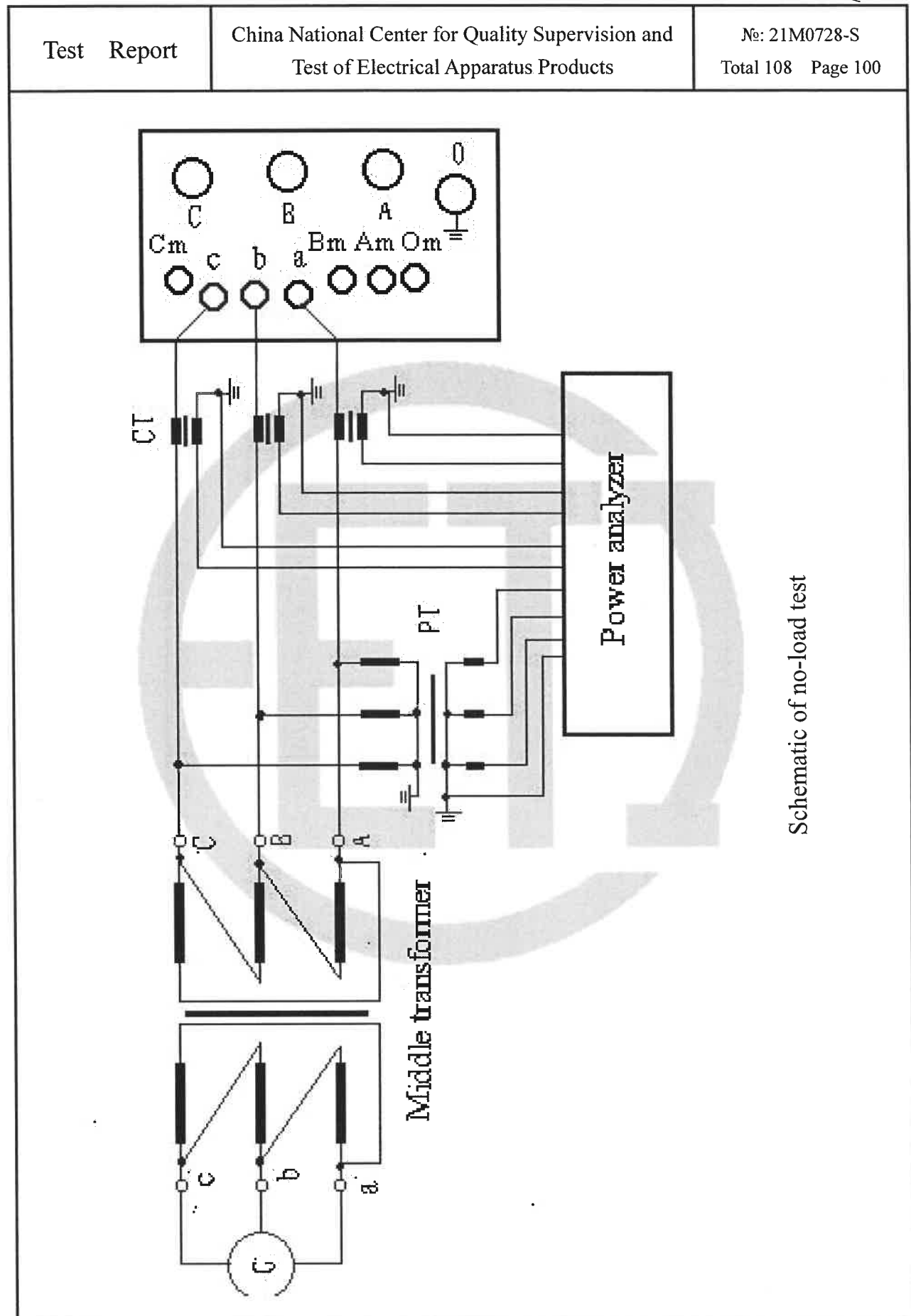
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HV side after short-circuit:



LV side after short-circuit:



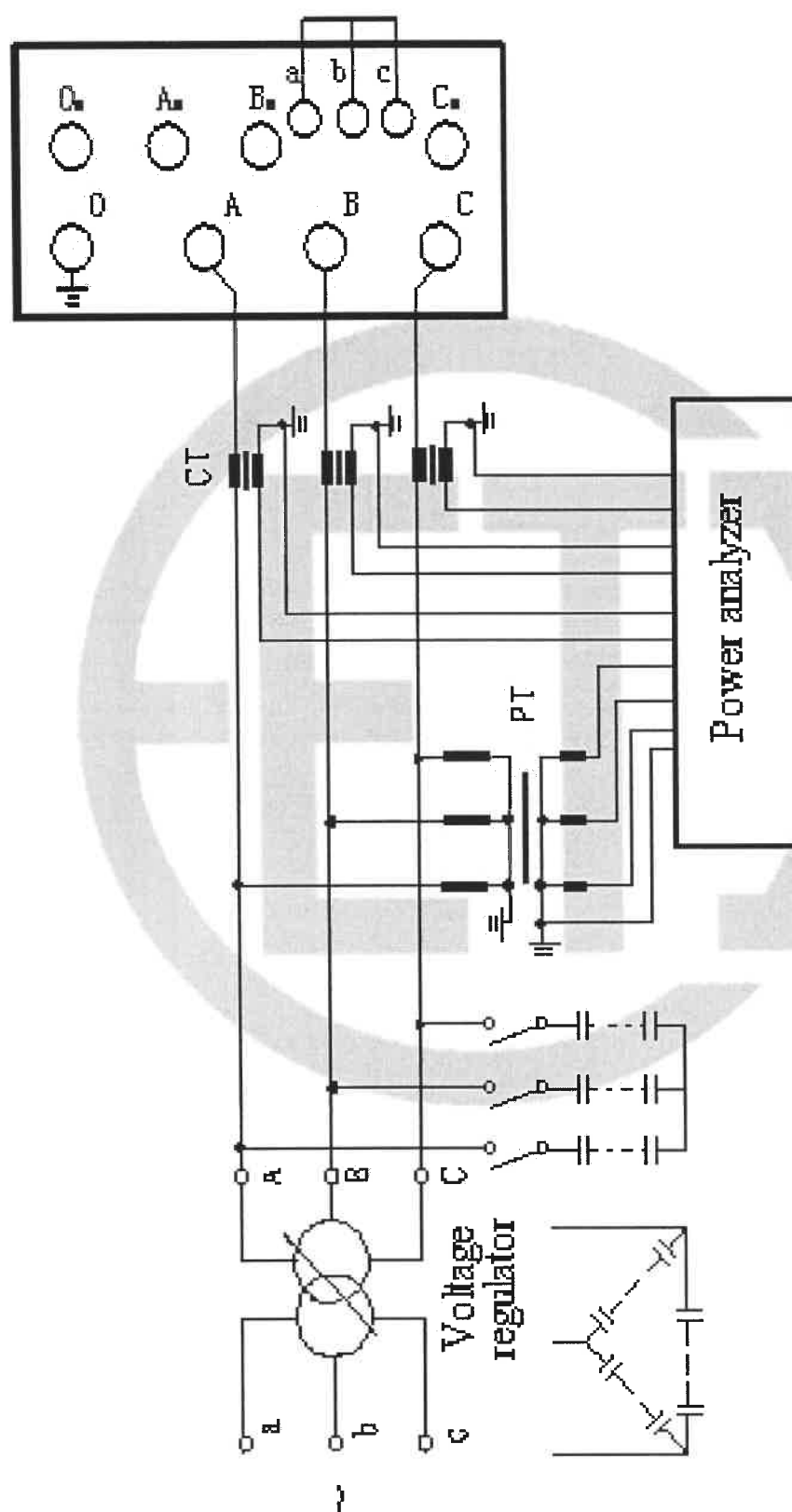


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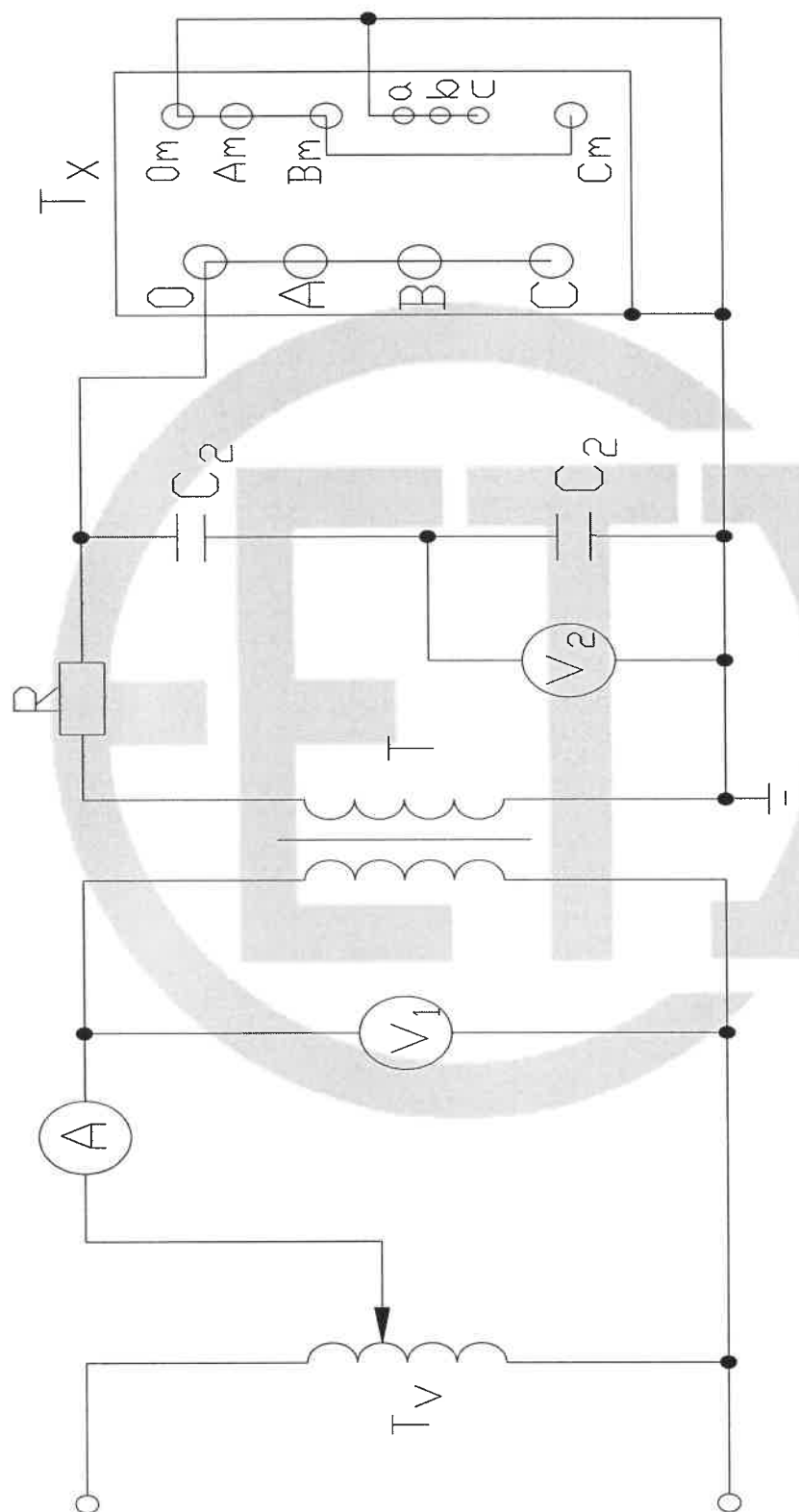
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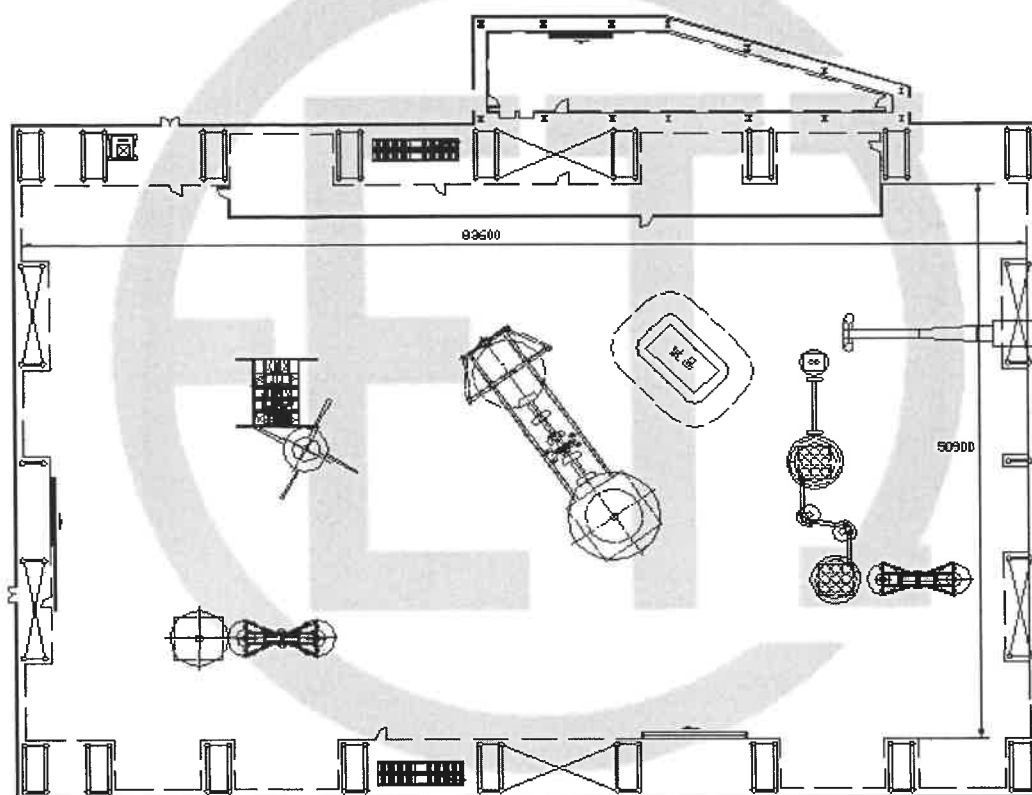


Schematic of load test



Schematic of separate-source AC withstand voltage test

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Sound levels arrangement diagram

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Instruments used in the tests					
No	Test items	Name & type of instrument	Number & validity		Accuracy level
1	Measurement of d.c. insulation resistance windings-to-earth and between windings	Digital mega-ohm meter F1550C	ER17-013	2021-04-25	/
2	Check of core and frame insulation for liquid-immersed transformers with core or frame insulation				
3	Measurement of dissipation factor (tanδ) of the insulation system capacitances	Movable insulation diagnostic and analysis system MIDAS2880	ER19-008	2021-03-19	Capacitance: ±0.3%rdg±0.3pF Inductance: ±0.5%rdg±0.5mH
4	Measurement of bushing capacitances and dielectric dissipation factor (tanδ)				
5	Determination of capacitances windings-to-earth and between windings				
6	Measurement of winding resistance	DC resistance tester JYR(50C)	ER16-032	2021-08-20	0.2%±0.2μΩ
7	Measurement of voltage ratio and check of phase displacement	Transformer ratio tester BBC6638	RI15-032	2021-04-06	/
8	Check of the ratio and polarity of built-in current transformers	Multi-function transformer ratio tester YTB	RI15-012	2022-02-21	ratio: ±0.2% phase: 0.2°
9	Measurement of short-circuit impedance and load loss	Transformer loss test system TMS580-200-4000	749-1573	2022-02-02	/
10	Measurement of no-load loss and current				
11	Measurement of no-load loss and current at 90% and110% of rated voltage				
12	Tests on on-load tap-changers				
13	Insulation test of auxiliary wiring	Power-frequency withstand voltage tester PFT-5C	745-102	2021-10-22	/
14	Switching impulse test	Assemblies testing equipment of impulse voltage generator 7200kV/1620kJ	750-027	2021-04-29	/
		Weakly damped capacitance voltage divider RZF-6500	750-027-3	2021-04-29	/
15	Separate-source AC withstand voltage test	Power-frequency partial discharge-free test power supply 2400kVA/8000kV	745-076	2021-04-28	/
16	Line terminal AC withstand test	Transformer loss test system TMS580-200-4000	749-1573	2022-02-02	/

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Instruments used in the tests					
No	Test items	Name & type of instrument	Number & validity		Accuracy level
17	Induced AC withstand voltage test with partial discharge measurement	Transformer loss test system TMS580-200-4000	749-1573	2022-02-02	/
		Partial discharge tester DDX9121b	745-077	2022-01-22	/
18	Insulating liquid test, measurement of dissolved gasses in dielectric liquid from each separate oil compartment except diverter switch compartment	High precision full-automatic capacitance, inductance and dielectric loss measuring bridge 2840-Combi	ER18-003	2021-07-21	±0.2%rdg±0.01pF ±0.5%rdg±1×10 ⁻⁵
		Automatic dielectric strength tester NRNY-1004	ER18-005	2021-12-02	±3%
		Moisture analyzer CA-200	CA02-002	2021-04-14	±3μg (water for 10μg to 1mg or above) RSD 0.3% or under (water for 1mg or above)
		Gas chromatogram analyzer 7890B	749-1732	2022-11-15	/
19	Temperature-rise test	Transformer loss test system TMS580-200-4000	749-1573	2022-02-02	/
		Thermocouple Type T	TT33-305	2021-04-02	/
		Data acquisition/switch unit 34970A	TT11-101	2021-04-02	DC V±0.01%, A±0.11% AC V±5.25%, A±1.5% T±1℃ Ω±0.81%
		DC resistance tester JYR(50C)	ER16-019	2021-12-22	0.2%±0.2μΩ
		DC resistance tester JYR(50C)	ER16-032	2021-08-20	0.2%±0.2μΩ
		Electronic stopwatch TA228	HT15-025	2021-05-31	/
		Infrared thermal camera TIS55	TT14-024	2021-07-01	/
20	Leak testing with pressure for liquid-immersed transformers	Intelligent pressure transmitter SY-PGD101-2.5MPa-GH	FP87-039	2022-02-04	/
21	Mechanical strength test of tank	Intelligent pressure transmitter SY-PGD101-2.5MPa-GH	FP87-039	2022-02-04	/
		Steel tapeline	LS05-032	2021-04-15	/
22	Measurement of the harmonics of the no-load current	Transformer loss test system TMS580-200-4000	749-1573	2022-02-02	/
23	Measurement of zero-sequence impedances on three-phase transformers				

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Instruments used in the tests					
No	Test items	Name & type of instrument	Number & validity		Accuracy level
24	Determination of sound levels	Transformer loss test system TMS580-200-4000	749-1573	2022-02-02	/
		Sound level meter 2250	SP01-030	2021-10-12	/
		Sound level calibrator	SP01-029	2021-07-20	/
		Steel tapeline	LS05-032	2021-04-15	/
25	Measurement of frequency response	Transformer winding deformation tester FRAX99	ER16-021	2022-03-04	/
26	Short-circuit withstand test	Data collection 1-GEN16T-2	EI56-019	2021-12-20	/
		LCR automatic tester UC2860XD	ER16-063	2021-07-29	/
		Voltage transformer TEMP-1000HU	EH112-001	2023-10-22	/
		Voltage transformer VEOS525	EH111-001	2022-09-24	/
		Voltage transformer VEOS525	EH111-002	2022-09-24	/
		Voltage transformer VEOS525	EH111-003	2022-09-24	/
		Current divider FLT1-30/2.5	EI30-016	2021-10-28	/
		Current divider FLT1-30/2.5	EI30-017	2021-10-28	/
		Current divider FLT1-30/2.5	EI30-018	2021-10-28	/
27	Measurement of dissipation factor (tanδ) of the insulation system capacitances	Movable insulation diagnostic and analysis system MIDAS2880	ER19-008	2022-03-04	Capacitance: ±0.3%rdg±0.3pF Inductance: ±0.5%rdg±0.5mH
28	Measurement of bushing capacitances and dielectric dissipation factor (tanδ)				
29	Determination of capacitances windings-to-earth and between windings				

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Instruments used in the tests					
No	Test items	Name & type of instrument	Number & validity		Accuracy level
30	Lightning impulse test	Assemblies testing equipment of impulse voltage generator 7200kV/1620kJ	750-027 2021-04-29		/
		Weakly damped capacitance voltage divider RZF-6500	750-027-3 2021-04-29		/
		Assemblies testing equipment of impulse voltage generator 1500kV/270kJ	750-028 2022-10-14		/
		Weakly damped capacitance voltage divider RZF-1500	750-028-2 2022-10-14		/
31	Long-duration no-load test	Transformer loss test system TMS580-200-4000	749-1573 2022-02-02		/
32	Measurement of no-load excitation characteristics				
33	Measurement of radio interference	Transformer loss test system TMS580-200-4000	749-1573 2022-02-02		/
		Electromagnetic interference measurement receiver ZN3950C	RP10-005 2021-11-19		/
		Standard signal generator ZN1060A	RI02-003 2021-04-08		/
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DECLARATION

1. The report is invalid without special seal for testing and page combining seal on the report;
2. The report is invalid if altered;
3. The report is invalid without signatures of persons for drawing up,
proof-reading, reviewing and approval;
4. The report is valid only for the inspected and tested samples.

NOTICE

1. In case there is any objection to this report, please raise it to the laboratory within fifteen days starting from the date of receiving the report, Thank you for your cooperation.
2. In case there is no objection, please take back the samples within one month starting from the date of receiving the report, when the manufacturer is going to take back the samples, certificate for sample taking and along with the written approval for the report should be brought in presence, only then the samples could be taken back. On time due, the samples will be in the laboratory's own disposal.

The test report is in total 108 pages including 54 figures and 3 photos

Typewriter Yuan Xiaoyong

Proofreader Meng Fanchao

Binder Yuan Xiaoyong

Address: No.5 Qianzhu Rd., Yuexi, Wuzhong District, Suzhou

Tel: (0512)66556600(switchboards) 68252753 68081201

Fax: (0512)68081686

Post code: 215104

<http://www.eeti.cn>

E-mail: [eservice @eeti.c](mailto:eservice@eeti.cn)

