NATIONAL INSTITUTE FOR RESEARCH, DEVELOPMENT
AND TESTING IN ELECTRICAL ENGINEERING
ICMET CRAIOVA
HIGH VOLTAGE DIVISION
Low and High Voltage Testing Laboratory
200746 CRAIOVA, Blvd. DECEBAL, No.118A, ROMANIA
Matriculation certificate: J16/312/1999, VAT number RO3871599
Phone: + 40 0351 402425, 404888; Fax: +40 0351 404890
www.icmet.ro ; E-mail: market@icmet.ro

accredited for TESTING
SR EN ISO/CEI 17025:2005
ACCREDITATION CERTIFICATE LI 1036

TEST REPORT
No. 45957 / 08.08.2017

1. CUSTOMER: NIKDIM Ltd.
Address: 23rd Shipchensky Polk No. 80, 6100 Kazanlak, Bulgaria

2. MANUFACTURER: NIKDIM Ltd.
Address: 23rd Shipchensky Polk No. 80, 6100 Kazanlak, Bulgaria

3. TESTED PRODUCT: Outdoor to Indoor Bushing type PrBO 10

4. REFERENCE STANDARD: IEC 60137 : 2017

5. PERFORMED TEST:

I – Dry lightning impulse voltage withstand test
II – Dry power frequency voltage withstand test
III – Wet power frequency voltage withstand test

6. TESTS DATE: 08.08.2017

7. TESTS RESULT: The product passed the test.

The test report contains 14 pages and is edited in 4 copies, copy no.1 remain in laboratory and copies 2÷ 4 are sent to the customer.

HEAD OF HVD – TECHNICAL MANAGER,
Dipl. eng. Ion BURCIU

ICMET DIVIZIA DE ÎNALTĂ TENSIUNE CRAIOVA

HEAD OF TESTING TEAM,
Dipl. eng. Ion BADEA

Warnings:

a. *The results refer only to the tested product.*
b. *Publication and reproduction of the contents of this report in any other form unless its complete photocopying is not allowed without writing approval of Division to which laboratory belongs.*
c. *All signatures of the present report are original ones.*

Content **Page**

1. **IDENTIFICATION OF THE TEST PRODUCT:** Outdoor to Indoor Bushing 10kV/400A

Type: PrBO 10

Serial / year: - / 2017

Technical Specification / Drawing: – / see page 14

Client test order: Contract no. 876 / 03.08.2017

Internal test order: 23362 / 07.08.2017

Product receiving date: 07.08.2017

Product condition at receiving: New

2. **MAIN TECHNICAL CHARACTERISTICS ESTABLISHED BY MANUFACTURER:**

Maximum working voltage(Um): ..... 12 kV

Rated current (Ir): 200A, 400A, 630A, 1000A

Dry lightning impulse withstand voltage 1.2 / 50 µs: ..... 75 kV_{peak}

Dry power frequency withstand voltage test: ..... 42 kV_{rms}

Wet power frequency withstand voltage test: ..... 28 kV_{rms}

Material : porcelain C110

Colour of glaze: brown

Note :
1. The dry power frequency withstand voltage test was performed at the customer request.
2. The level of dry and wet power frequency withstand voltages was specified by customer.

3. **TESTS PROGRAM:**

I – Dry lightning impulse voltage withstand test
II – Dry power frequency voltage withstand test
III – Wet power frequency voltage withstand test

4. **RESPONSIBLE FOR TEST:** Dipl. eng. Laurenţiu Vlădoi (I)
Dipl. eng. Dan Ştefan (II, III)

5. **PRESENT AT TESTS:** General Manager eng. Maria Georgieva – NIKDIM Bulgaria

I. DRY LIGHTNING IMPULSE VOLTAGE WITHSTAND TEST

1. Test date: 08.08.2017
2. Test standard: IEC 60137 : 2017 subclause 8.4
3. Equipment used:
- Impulse generator 4.2 MV, no. 5 – 1197; connection I_1 (1 x 1);
- C_s = 0.576 [μF]; R_s = 47 [Ω]; R_p = 115 [Ω].

Addenda: C_s – equivalent capacity of impulse generator;
R_s – equivalent serial resistance of impulse generator;
R_p – equivalent parallel resistance of impulse generator.

Measuring system used:
- High voltage measuring system of impulse generator 4.2 MV consists of:
  - Capacitive divider of the impulse generator 4.2 MV with k_{div} = 345.1;
  - Digital measuring system type TR – AS 100 – 10 / 4, no.228; channel 2. (Calibration Certificate no. 91 / 12.2016)

Measuring uncertainty for: peak value of lightning impulse is: ± 1.38 %
- for front time T_1 is ± 8.44 %,
- for tail time T_2 is ± 3.39 %.

The uncertainty stated is expanded uncertainty obtained by multiplying the standard uncertainty by the coverage factor k = 2. The value of measurand lies within the assigned range of values with probability of 95%.

4. Test procedure / Test set-up: according to IEC 60137 : 2017, subclause 8.4.

5. Atmospheric conditions; correction factors; U_{test}

Atmospheric conditions:	p [mbar]	1005
	t [°C]	26
	h_r [%]	53
Arcing distance measured [mm]:		185
Correction factors:	k_1	0.9782
	k_2	1.0174
	$k_t = k_1 \cdot k_2$	0.9952
$U_{test}(p_0,t_0,h_0)$ (-) and (+) [kV_{peak}]:		**75**
$U_{test}(p, t, h) = k_t \cdot U_{test}(p_0,t_0,h_0)$:		**74.6**

Symbols used:
- $U_{test}(p_0, t_0, h_0)$ – rated withstand voltage value;
- $U_{test}(p, t, h)$ – test voltage corrected to atmospheric conditions;

6.Test circuit diagram:

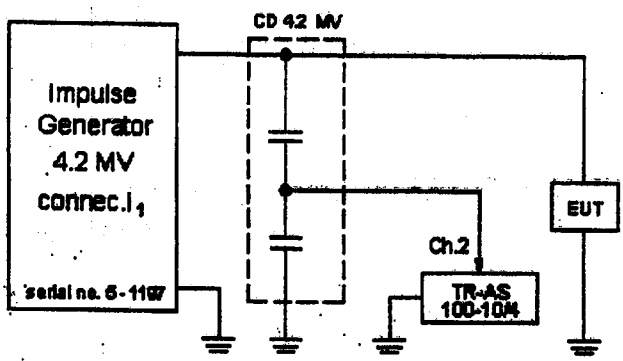


Fig. 1
Legend: EUT – Equipment under test

Notes:

1. The test was performed applying successively 15 voltage impulses of positive polarity and 15 voltage impulses of negative polarity (see photos from page 5).
2. The standard 1.2 / 50 µs lightning impulse was used. For wave parameters see oscillograms from pages 6 + 10.

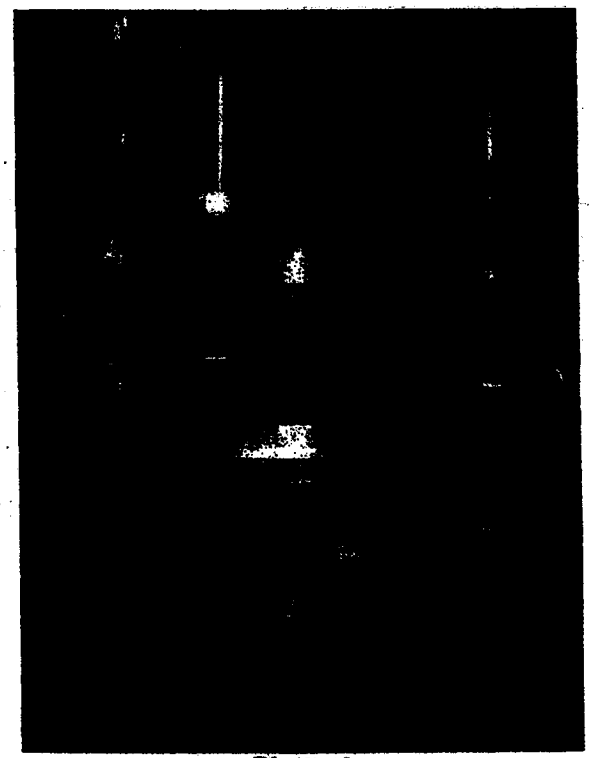


Photo 1

7.Test result: The product passed the test.

II. DRY POWER FREQUENCY VOLTAGE WITHSTAND TEST

1. **Test date:** 08.08.2017
2. **Test standard:** IEC 60137 : 2017, subclause 8.2.
3. **Equipment used:**
   – Test transformer 350 kVA / 350 kV, no.3 – 1963

   Measuring system:
   – AC measuring system 350 kV consists of:
   - high voltage compressed gas capacitor type MCF 75 / 350P, no.853889 and low voltage arm type H90, no.898939;
   - digital peak voltmeter type MU-17, no. 910396;
   - coaxial measuring cable, 75Ω.

   (Calibration Certificate no.41 / 04.2015).

Measuring uncertainty is ± 1.6 %..
The reported uncertainty is an expanded uncertainty, based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95 %.

4.Test procedure / Test set-up: according to IEC 60137 : 2017, subclause 8.2

5. Atmospheric condition, correction factors, U_{test}

Atmospheric conditions:	p [mbar]	1005
	t [°C]	26
	h_r [%]	53
Arcing distance measured [mm]:		185
Correction factors:	k_1	0.9955
	k_2	1.0042
	$k_t = k_1 \cdot k_2$	0.9997
Frequency: [Hz]		50
Time: [sec]		60
$U_{test}(p_0,t_0,h_0)$: [kV_{rms}]		**42**
$U_{test}(p, t, h) = k_t \cdot U_{test}(p_0,t_0,h_0)$:		**41.98**

Symbols used:
– U_{test} (p_0, t_0, h_0) – rated withstand voltage value;
– U_{test} (p, t, h) – test voltage corrected to atmospheric conditions.

6. Test circuit diagram:

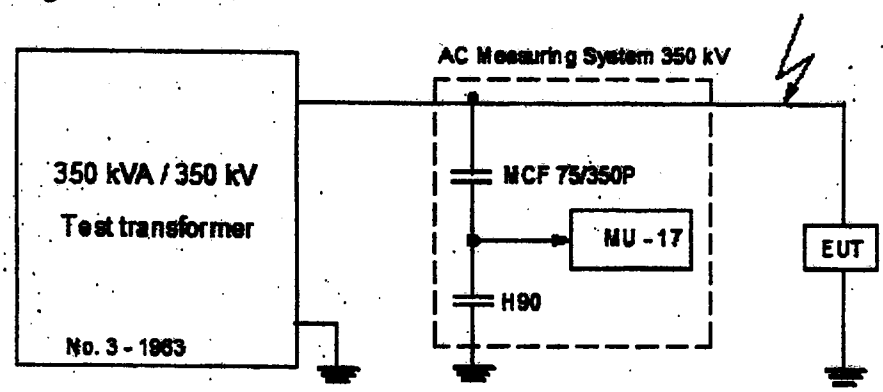


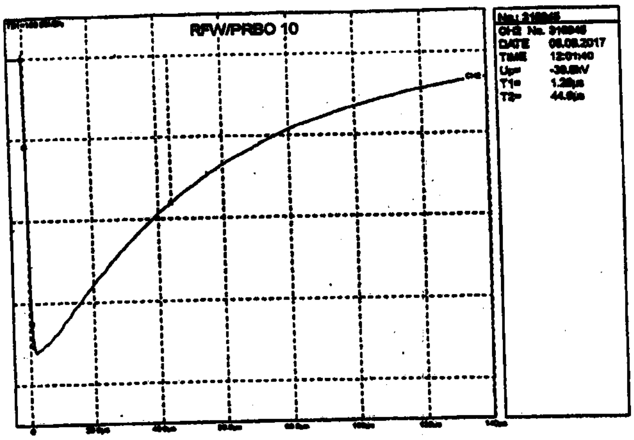
Fig. 2

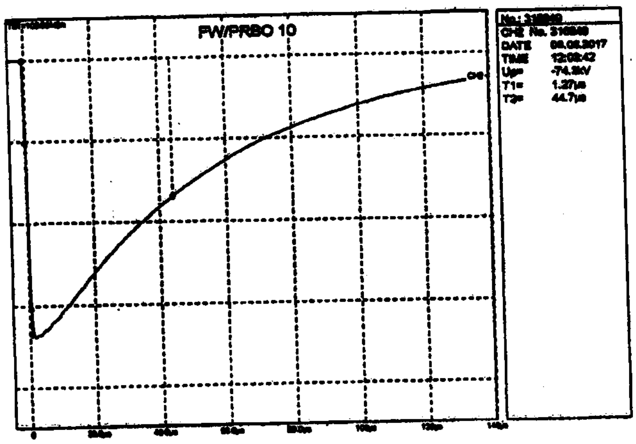
7.Test result: The product passed the test.

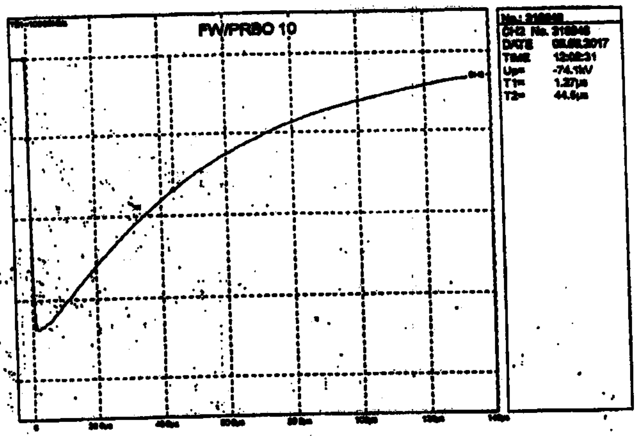
LI lightning-impulse						
no.	Up [kV]	T1[µs]	T2[µs]	Tc[µs]	Ip[A]	remark
316945	-39.6	1.26	44.6			RFW/PRBO 10
316946	-74.1	1.27	44.5			FW/PRBO 10
316947	-73.7	1.27	44.6			FW/PRBO 10
316948	-74.5	1.27	44.6			FW/PRBO 10
316949	-74.3	1.27	44.7			FW/PRBO 10
316950	-74.5	1.27	44.7			FW/PRBO 10
316951	-74.8	1.27	44.6			FW/PRBO 10
316952	-74.3	1.27	44.7			FW/PRBO 10
316953	-74.3	1.27	44.7			FW/PRBO 10
316954	-74	1.27	44.6			FW/PRBO 10
316955	-74.9	1.27	44.5			FW/PRBO 10
316956	-74.6	1.27	44.5			FW/PRBO 10
316957	-75.1	1.27	44.5			FW/PRBO 10
316958	-74.9	1.27	44.7			FW/PRBO 10
316959	-75	1.27	44.5			FW/PRBO 10
316960	-75.3	1.27	44.6			FW/PRBO 10
316961	43.2	1.26	43.8			RFW/PRBO 10
316962	74.6	1.28	44.7			FW/PRBO 10
316963	74.3	1.27	44.7			FW/PRBO 10
316964	75.2	1.27	44.6			FW/PRBO 10
316965	74.2	1.27	44.7			FW/PRBO 10
316966	75.2	1.27	44.7			FW/PRBO 10
316967	74.9	1.27	44.7			FW/PRBO 10
316968	74.3	1.27	44.8			FW/PRBO 10
316969	74.8	1.27	44.6			FW/PRBO 10
316970	74.6	1.27	44.7			FW/PRBO 10
316971	75.1	1.27	44.7			FW/PRBO 10
316972	74.4	1.27	44.7			FW/PRBO 10
316973	74.8	1.27	44.6			FW/PRBO 10
316974	73.9	1.27	44.6			FW/PRBO 10
316975	74.8	1.27	44.7			FW/PRBO 10
316976	74.8	1.27	44.8			FW/PRBO 10

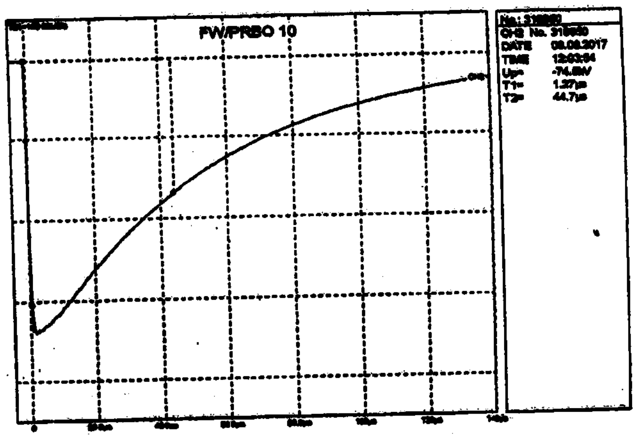
Notes: 1.UP-peak value of testing voltage; T1, T2, T_c – front, tail and chopping time – parameters of testing impulse wave;

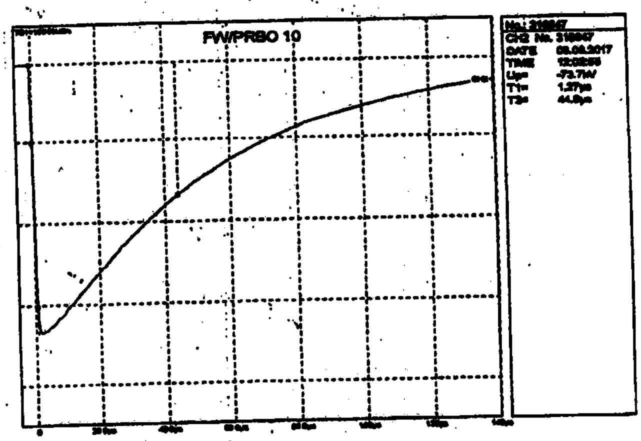
2. RFW – reduced wave 50 – 75%; FW – full wave 100%

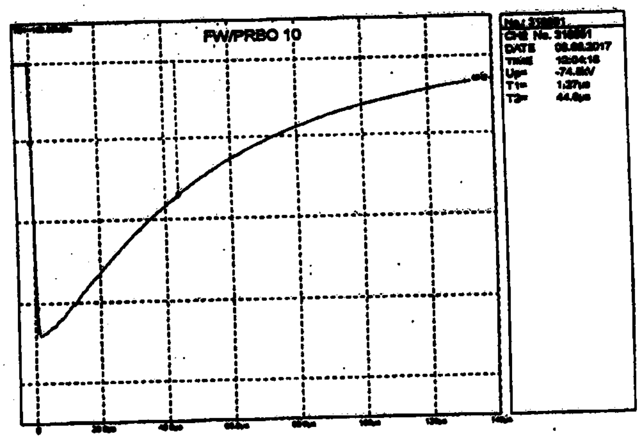


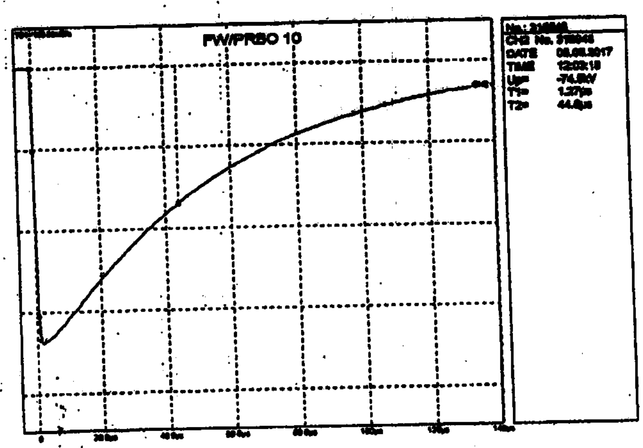


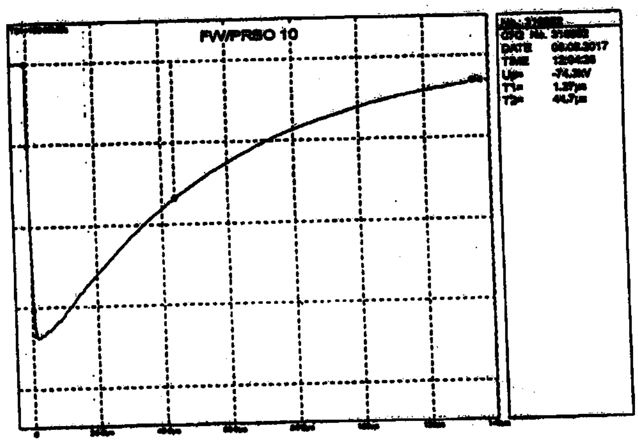


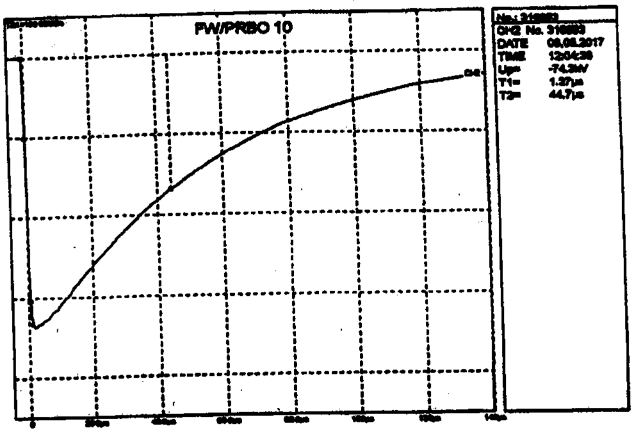


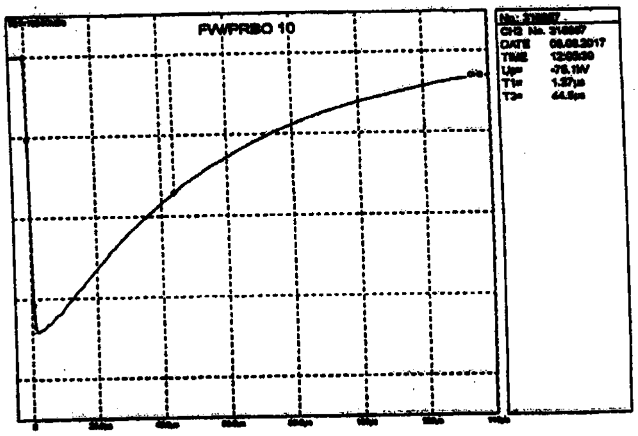


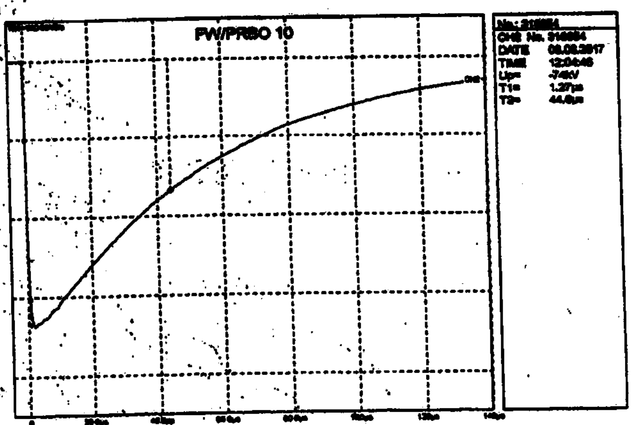


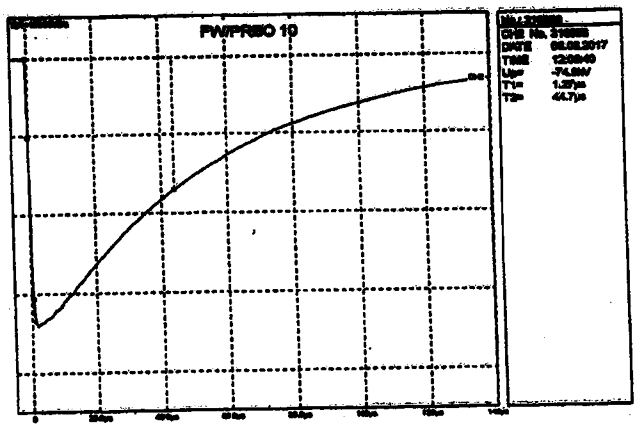


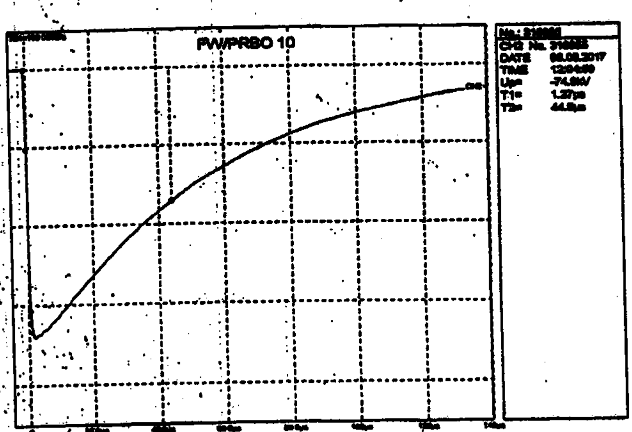


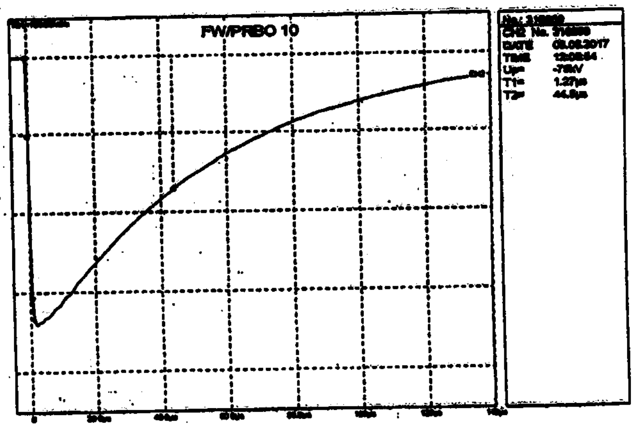


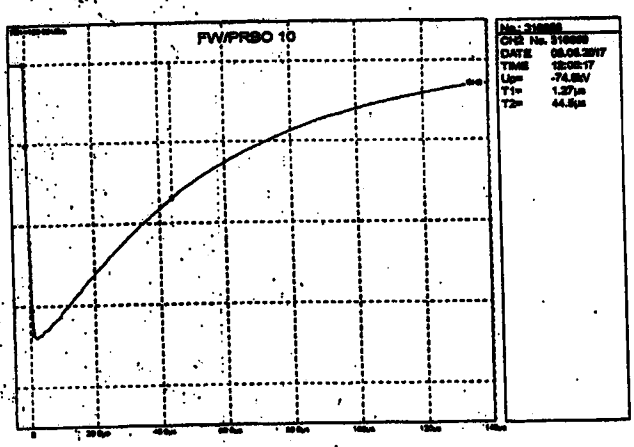


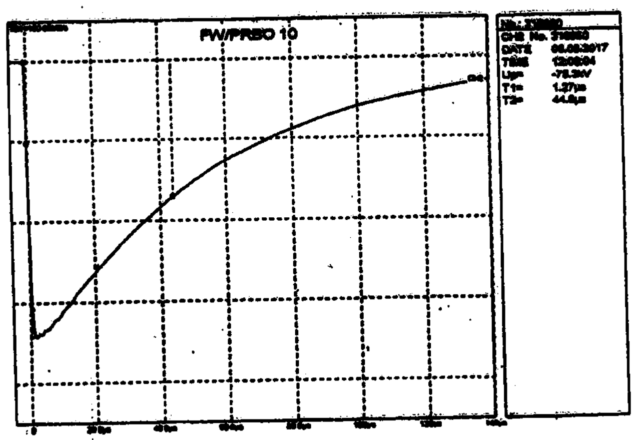


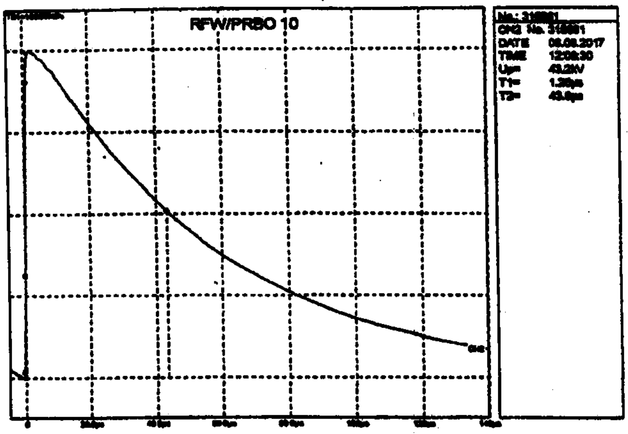


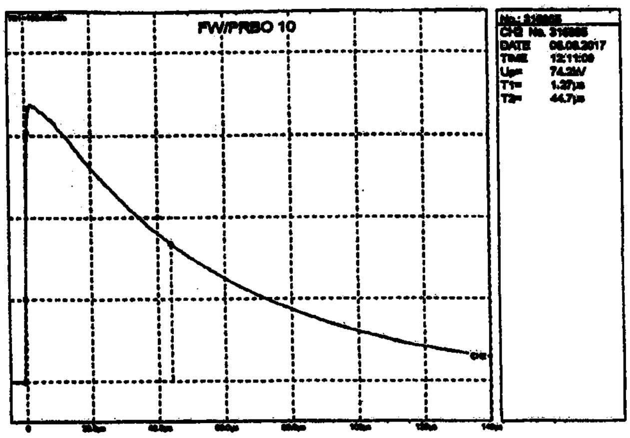


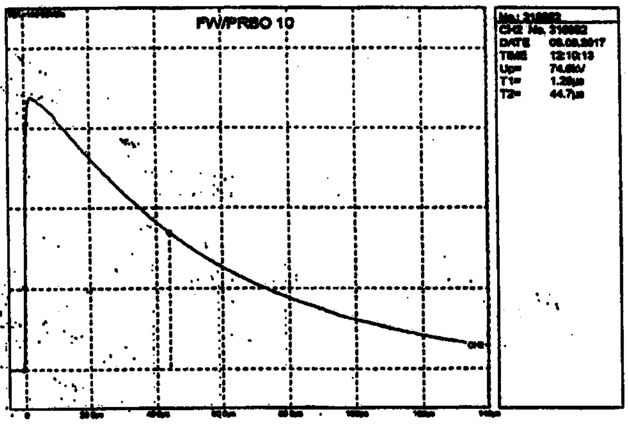


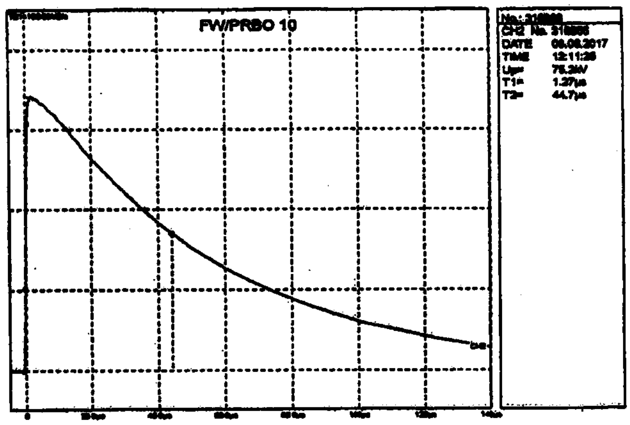


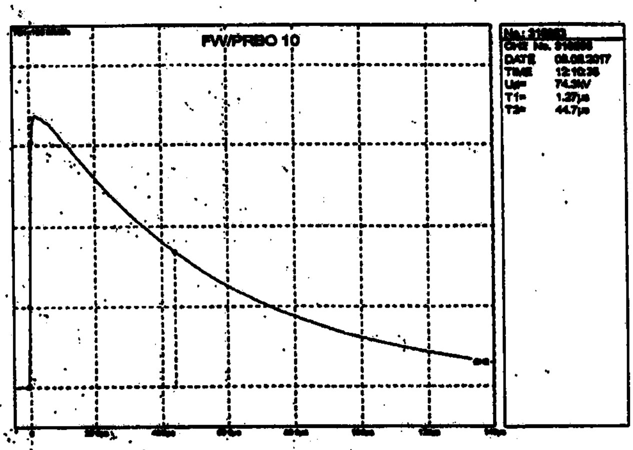


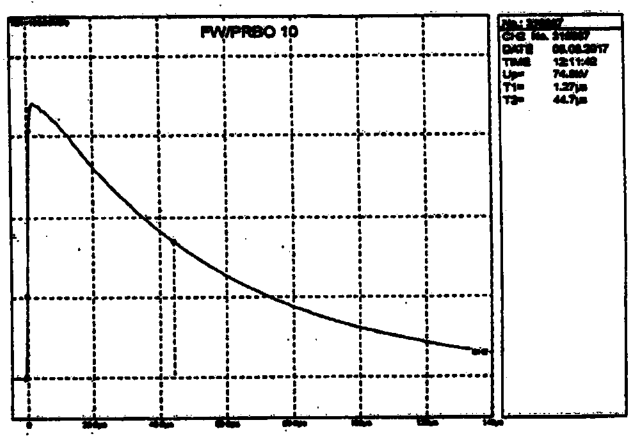


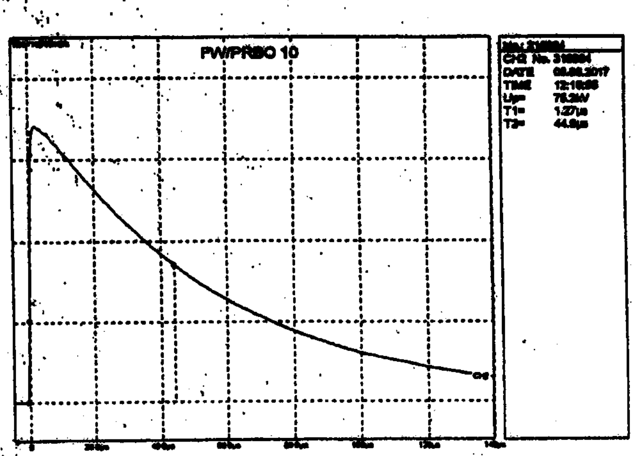


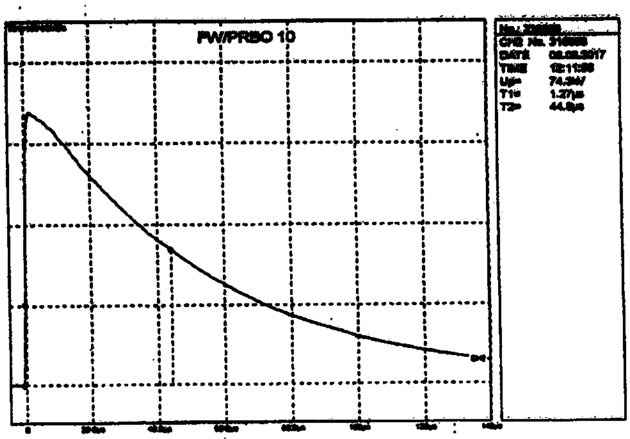


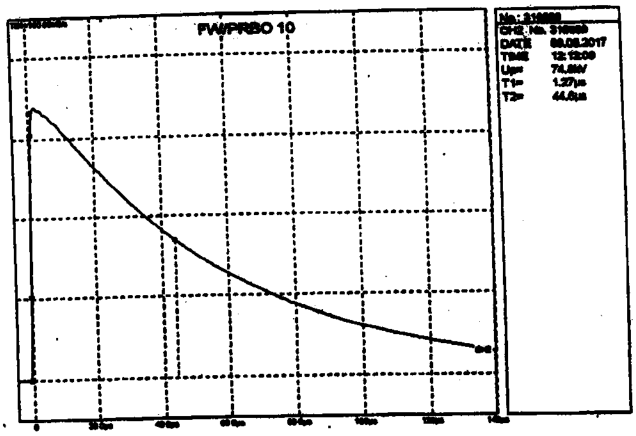


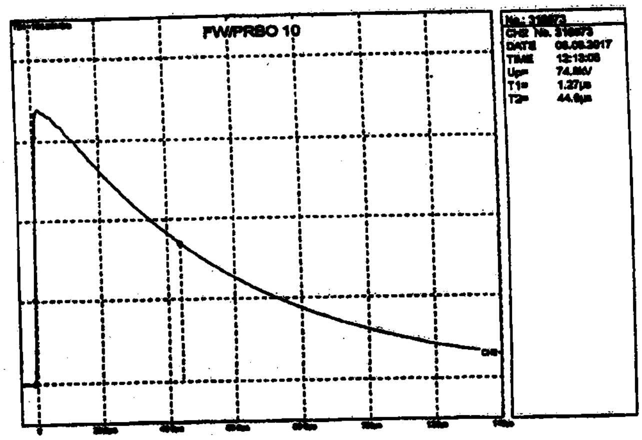


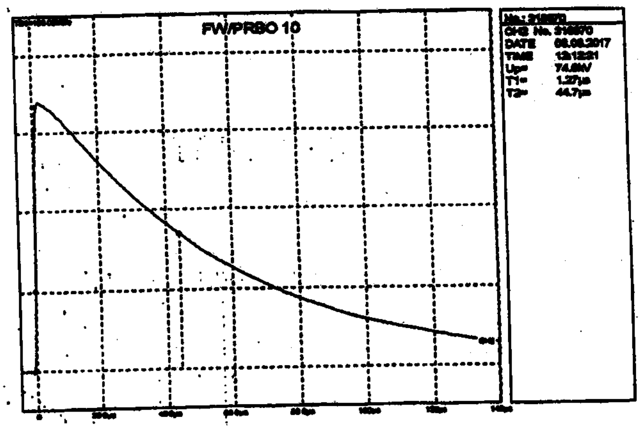


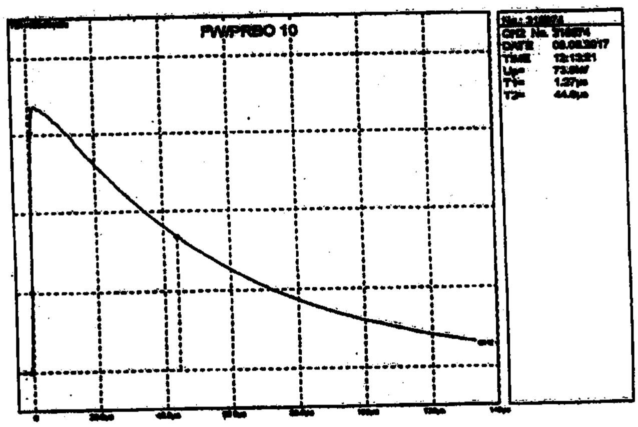


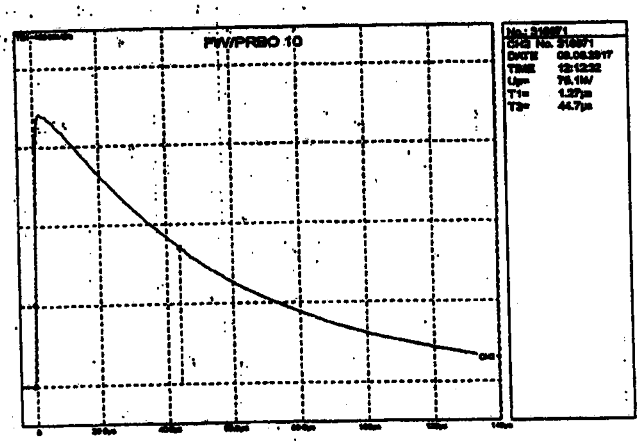


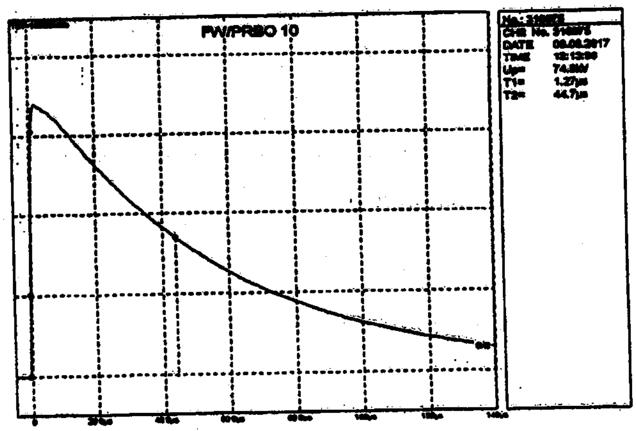


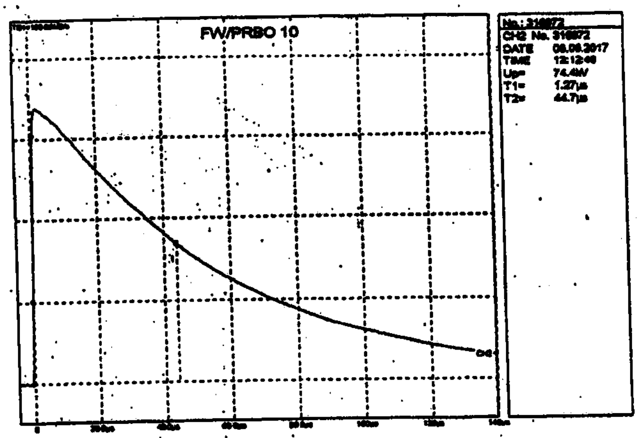


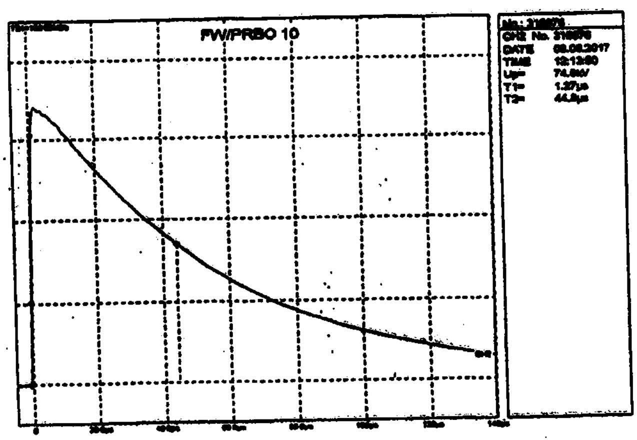












II. DRY POWER FREQUENCY VOLTAGE WITHSTAND TEST

1. **Test date:** 08.08.2017
2. **Test standard:** IEC 60137 : 2017, subclause 8.2.
3. **Equipment used:**
   – Test transformer 350 kVA / 350 kV, no.3 – 1963

   Measuring system:
   – AC measuring system 350 kV consists of:
   - high voltage compressed gas capacitor type MCF 75 / 350P, no.853889 and low voltage arm type H90, no.898939;
   - digital peak voltmeter type MU-17, no. 910396;
   - coaxial measuring cable, 75Ω.

   (Calibration Certificate no.41 / 04.2015).

Measuring uncertainty is ± 1.6 %..
The reported uncertainty is an expanded uncertainty, based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95 %.

4.Test procedure / Test set-up: according to IEC 60137 : 2017, subclause 8.2

5. Atmospheric condition, correction factors, U_{test}

Atmospheric conditions:	p [mbar]	1005
	t [°C]	26
	h_r [%]	53
Arcing distance measured [mm]:		185
Correction factors:	k_1	0.9955
	k_2	1.0042
	$k_t = k_1 \cdot k_2$	0.9997
Frequency: [Hz]		50
Time: [sec]		60
$U_{test}(p_o,t_o,h_o)$: [kV_{rms}]		**42**
$U_{test}(p, t, h) = k_t \cdot U_{test}(p_o,t_o,h_o)$:		**41.98**

Symbols used:
– U_{test} (p_o, t_o, h_o) – rated withstand voltage value;
– U_{test} (p, t, h) – test voltage corrected to atmospheric conditions.

6. Test circuit diagram:

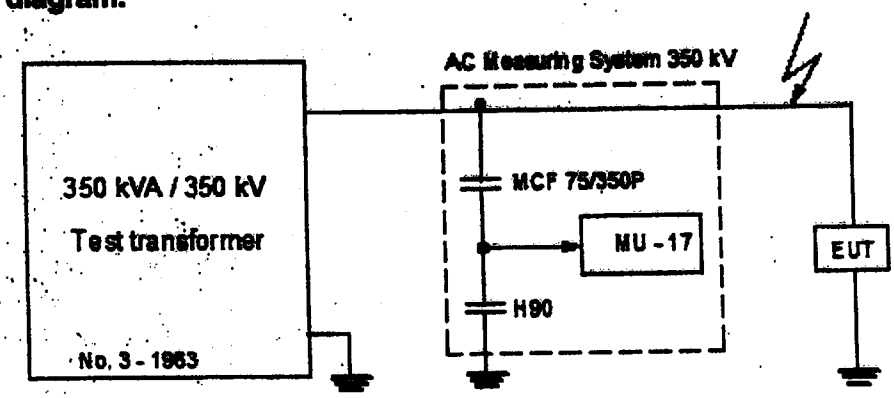


Fig. 2

7.Test result: The product passed the test.

III. WET POWER FREQUENCY VOLTAGE WITHSTAND TEST

2. **Test date:** 08.08.2017
2. **Test standard:** IEC 60137 : 2017, subclause 8.2.
3. **Equipment used:**
   - **for power frequency voltage:**
   - Test transformer 350 kVA / 350 kV, no.3 – 1963
   - **for rain:**
   - Artificial rain installation, serial no. 3 – 29.

Measuring system:
- AC measuring system 350 kV consists of:
  - high voltage compressed gas capacitor type MCF 75 / 350P, no.853889 and low voltage arm type H90, no.898939;
  - digital peak voltmeter type MU-17, no. 910396;
  - coaxial measuring cable, 75Ω.

(Calibration Certificate no.41 / 04.2015).

Measuring uncertainty is ± 1.6 %..
The reported uncertainty is an expanded uncertainty, based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95 %.

- **For measuring the parameters of the water have been used:**
  - liquid glass thermometer series 41
    (Calibrate Certificate no. DJ 013.141 – 552 / 2012 – BRML Craiova)
  - conductometer type 3210 serial no. 15440615 encompassing conductivity cell type TetraCon 325, series 15440175
    (Calibrate Certificate no. 132.05 – 03.2016)

Measuring uncertainty for thermometer is equal with 0.4% / ^{0}C and for conductometer is ± 3.2%.
The reported uncertainty is an expanded uncertainty, based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95 %.

4. **Test procedure / Test set-up:** according to IEC 60137 : 2017, subclause 8.2
5. **Atmospheric condition, correction factors, water parameters, U_{test}**

Atmospheric conditions:	p [mbar]	1005
	t [^{0}C]	26
	h_r [%]	53
Arcing distance measured [mm]:		185
Correction factors:	k_1	0.9955
	k_2	1
	$k_t = k_1 \cdot k_2$	0.9955
Precipitation conditions:	Temp [^{0}C]	25.4
	Apr-vc(2 [mm/min]	1.6
	Apr-hc [mm/min]	1.5
	Water conductivity [µS/cm]	98
Frequency: [Hz]		50
Time: [sec]		60
$U_{test}(p_0,t_0,h_0)$: [kV_{rms}]		**28**
$U_{test}(p, t, h) = k_t \cdot U_{test}(p_0,t_0,h_0)$:		**27.87**

Symbols used:
- U_{test} (p_0, t_0, h_0) – rated withstand voltage value;
- U_{test} (p, t, h) – test voltage corrected to atmospheric conditions.

6. Test circuit diagram:

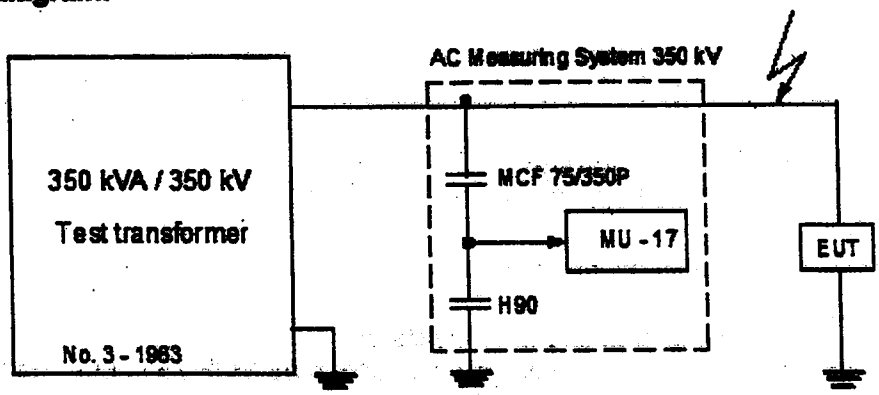
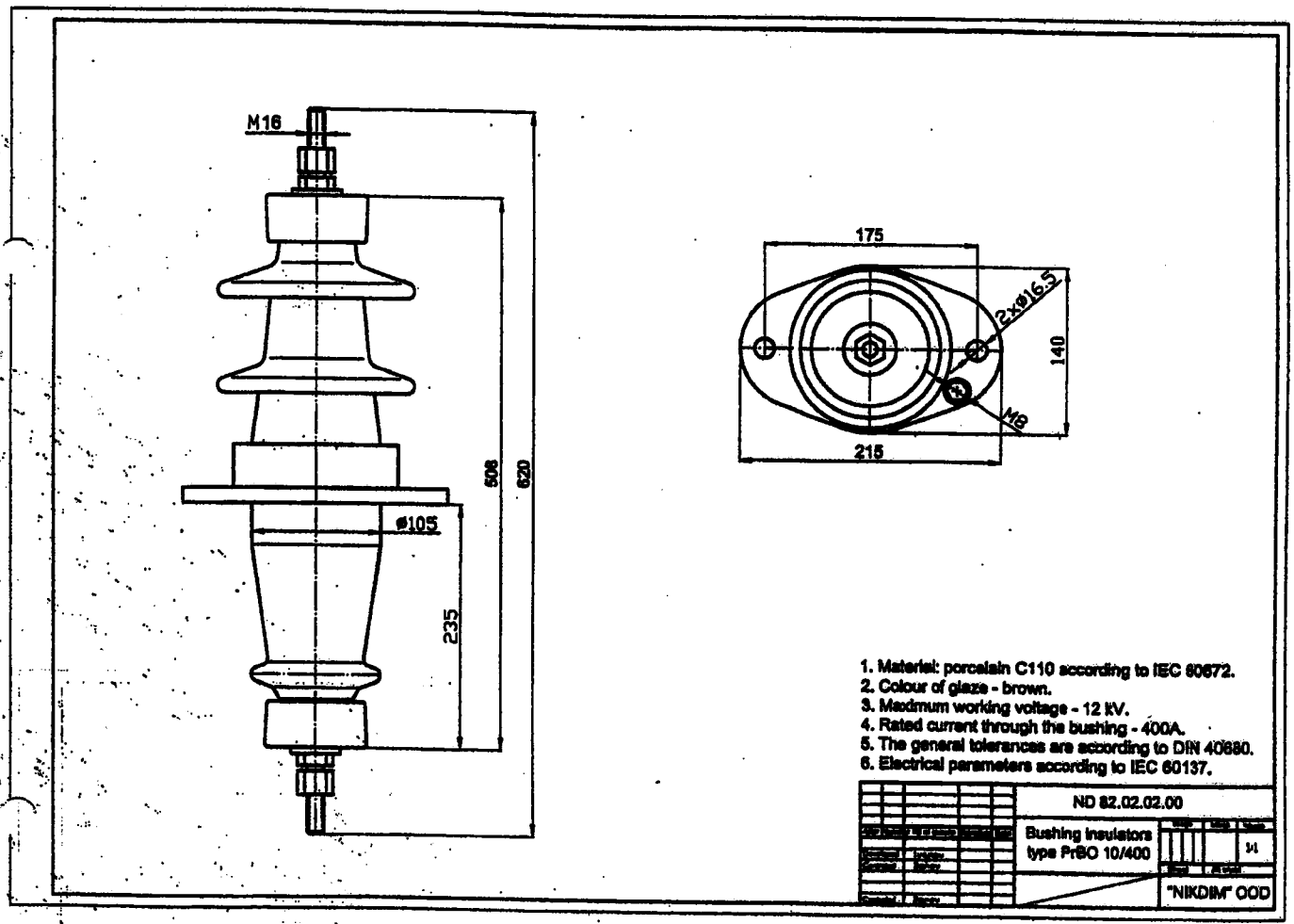


Fig. 3

7.Test result: The product passed the test.



– end of test report –

RESEARCH-DEVELOPMENT AND TESTING NATIONAL INSTITUTE FOR ELECTRICAL ENGINEERING

ICMET CRAIOVA

HIGH POWER DIVISION

HIGH POWER LABORATORY

"Ovidiu Rarinca"

200746 CRAIOVA, Blvd. DECEBAL, No.118A, ROMANIA

Matriculation certificate: J16/312/1999, VAT number RO387 1599

Phone: (351) 402 427; Fax: (351) 404 890;

www.icmet.ro ; E-mail: lmp@icmet.ro, market@icmet.ro

TEST REPORT

No. 12628

CUSTOMER: **NIKDIM Ltd.**
80, 23rd Shipchenski Polk. Blvd. 6100 Kazanlak – BULGARIA

MANUFACTURER: **NIKDIM Ltd.**
80, 23rd Shipchenski Polk. Blvd. 6100 Kazanlak - BULGARIA

TESTED PRODUCT: 12 kV, 400 A Indoor/Outdoor Insulated Bushings

REFERENCE STANDARD: IEC 60137:2017

TEST PERFORMED: Temperature-rise test
Verification of thermal short-time current withstand

TEST DATE: 08-11.08.2017

TEST RESULT: Passed the tests

Test Report has 9 pages and it is edited in 4 original copies from which copy 1 for Laboratory and copies 2, 3 and 4 for Customer.

TECHNICAL MANAGER OF HIGH POWER DIVISION
Phys. Daniel TRUTA

ICMET CRAIOVA * DE MARE PUTERE * LABORATORUL "OVIDIU RARINCA"

HEAD OF LABORATORY
Eng. Catalin DOBREA

DATE OF ISSUE: 11.08.2017

1. Results refer to test product only.

2. Publication or reproduction of the contents of this report in any other form unless its complete photocopying is not allowed without writing approval of division to which laboratory belongs to.

Content

1. IDENTIFICATION OF TESTED PRODUCT

1.1 General informations

Type	PRBO 10/400
Serial number	- / -
Contract No.:	705.2 / 876 / 03.08.2017
Product receiving date:	08.08.2017
Product condition at receiving:	New

1.2 Technical characteristics of the tested object

Rated voltage	12 kV
Rated normal current	400 A
Rated frequency	50 Hz
Rated short - time withstand current:	
- r.m.s. value	10 kA
Rated duration of short-circuit	1 s

1.3 Description of the tested object

An Indoor/Outdoor Air-Air Porcelain Insulated Bushings.

1.4 List of drawings

The manufacturer has guaranteed that the object submitted for tests has been manufactured in accordance with the following drawings. ICMET has verified that these drawings adequately represent the tested object. The manufacturer is responsible for the correctness of these drawings and the technical data presented.

The following drawings have been included in this test report:

Drawing number	Revision
ND 82.02.02.00	01

2. TESTS PROGRAM

2.1. One temperature-rise test at In = 400 A / 50 Hz acc. to cl. 8.8 of IEC 60137 with supply by copper cables of 240 mm^2 cross section, in test circuit from Figure 1.
2.2. Verification of thermal short-time current withstand by calculation acc. to cl. 8.9 of IEC 60137.

3. ACCURACY OF MEASUREMENT

The guaranteed uncertainty for the measured voltages and currents taking in account the total measuring system, is less than 3%, unless mentioned otherwise.

4. RESPONSIBLE FOR TESTS: Eng. Catalin Boltasu

5. PRESENT AT THE TESTS: Eng. Maria Georgieva from NIKDIM Ltd / BULGARIA

6. TEST REPORT DOCUMENTATION: Oscillograms: - Drawings: 1
Photos: 1

7. TEMPERATURE RISE TEST

7.1 Test circuit for temperature rise test

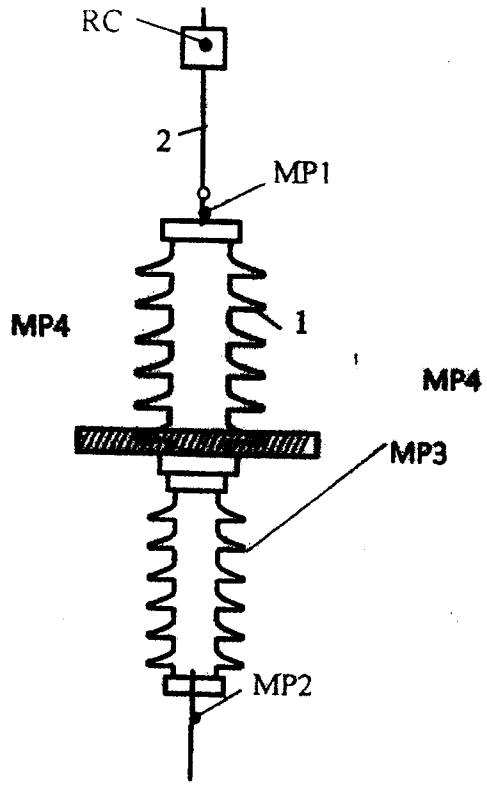


Figure I – Test circuit and measuring points for temperature-rise test

7.2 Results obtained at tests

The temperature rise test was performed having a current of 400 A / 50 Hz going through the bushing until the temperature variation did not exceed 1 K per hour.
Current supply was made with cooper cable dimensions: 1x240 mm^2 cross-section connected to the terminals of the bushings. Temperatures were measured using a temperatures measurement computerized system with type J thermocouple Keithley Multimeter Integra 2700.
Measurement points are presented in Figure 1. Environment temperature was measured in three points equally distributed around the Porcelain Bushing at half of its height and approximately 1 m distance of it. Values of the measured temperatures are presented in table below.

MP no.	Placement of MP	Nature of the part	Material	Maxim value of temperature-rise [K]	Final temperature [°C]	Temperature-rise [K]
MP1	Upper terminals	Screwed contacts	Cu/Cu-Silver	85	78.27	49.57
MP2	Lower terminals	Screwed contacts	Cu-Silver/Cu	85	77.52	48.82
MP3	Insulator		Porcelain	-	34.44	5.74
MP4	Ambient air 1)	-	-	-	28.70	-

1) Average value of 3 measurement points

The temperature rise on cable at 0.5 m distance from upper terminals (MP5 and MP6) was 22.57 K in upper part and 21.14 K in lower part.

8. THERMAL SHORT-TIME CURRENT VERIFICATION BY CALCULATION

The ability of the bushings to withstand the standard value of I_{th} is demonstrated by the following calculation:

$$\theta_f = \theta_0 + \alpha \frac{I_{th}^2}{S_t \times S_e} \times t_{th}$$

where

- θ_f is the final temperature of the conductor, in degrees Celsius;
- θ_o is the temperature of the conductor in degrees Celsius, under continuous operation with *Ir* at an ambient temperature of 40 °C;
- α is 0.8 (K/s)/(kA/cm^2)^2 for copper and 1.8 (K/s)/(kA/cm^2)^2 for aluminium;
- t_{th} is the rated duration as specified, in seconds;
- I_{th} is the standard value as specified above, in kiloamperes;
- S_e is the equivalent cross-section, in square centimetres, taking account of skin effect;
- S_t is the total cross-section, in square centimetres corresponding to *Ir*.

For other materials the value of α used may be derived from the formula given below:

$$\alpha = \rho/(c*\delta)$$

where

- ρ is the resistivity of conductor, in μΩ.cm (ρ=1.68 μΩ.cm for copper)
- *c* is the specific heat of conductor, in J/(g.K)
- δ is the density of the conductor, in g/cm$_3$.

The skin effect may be determined by considering a depth of penetration *d* of current derived from the formula given below:

$$d = \frac{1}{2\pi} \times \sqrt{\frac{\rho \times 10^3}{f}} \text{ cm}$$

where *f* is the rated frequency (Hz).

For ρ=1.68 $\mu\Omega$.cm (copper) and f=50 Hz it results d=0.92 cm therefore $S_e = \pi*d*(D-d) =$ = 1.96 cm^2 and $S_t = \pi*D^2/4$ = 2.01 cm^2 (for D=1.6 cm)

For I_{th}=10 kA and t_{th}=1 s it follows: θ_f=81.17 °C <180 °C as required in clause 8.9.3.

9. TEST RESULT:

12 kV, 400 A Indoor/Outdoor Insulated Bushings verified the acceptance criteria from cl. 8.8.3 and 8.9.3.

12 kV, 400 A Indoor/Outdoor Insulated Bushings passed the temperature-rise test and the verification of thermal short-time current by calculation.

- END OF DOCUMENT –

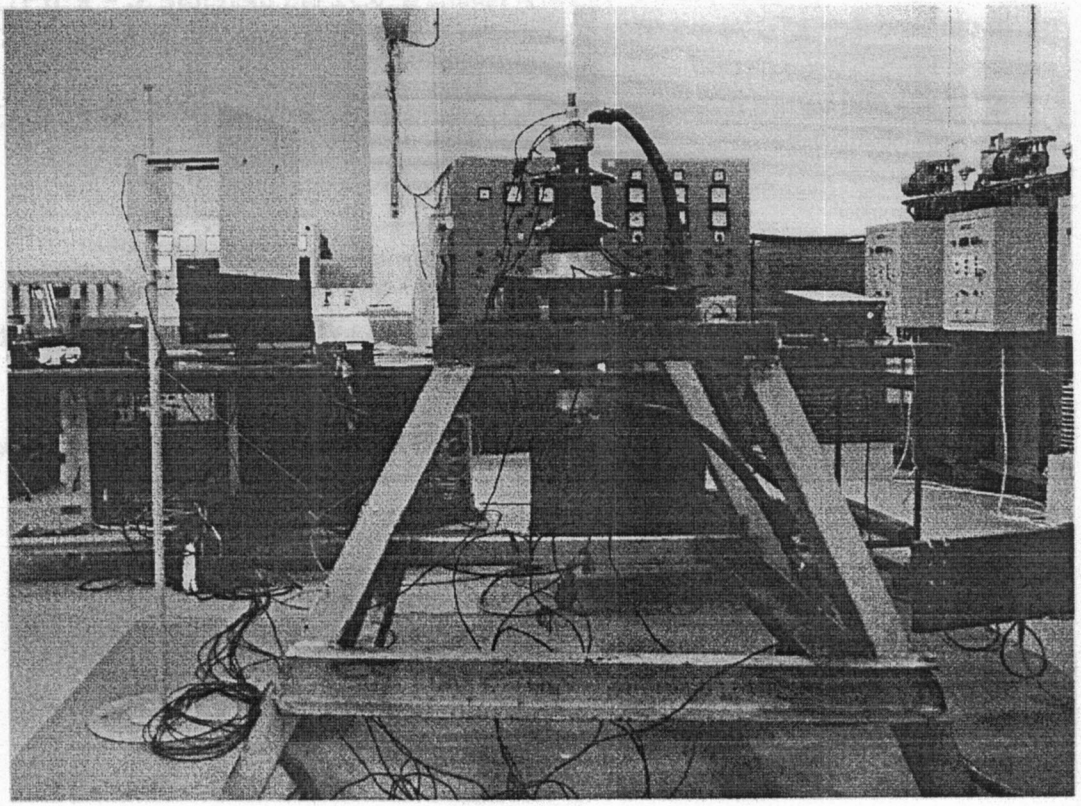
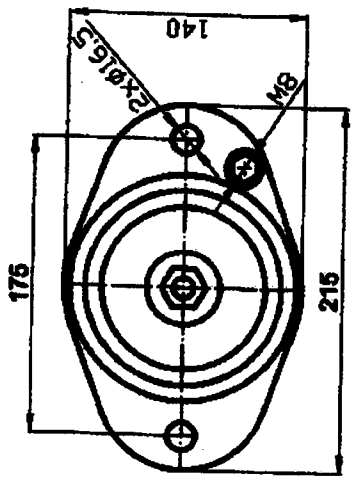
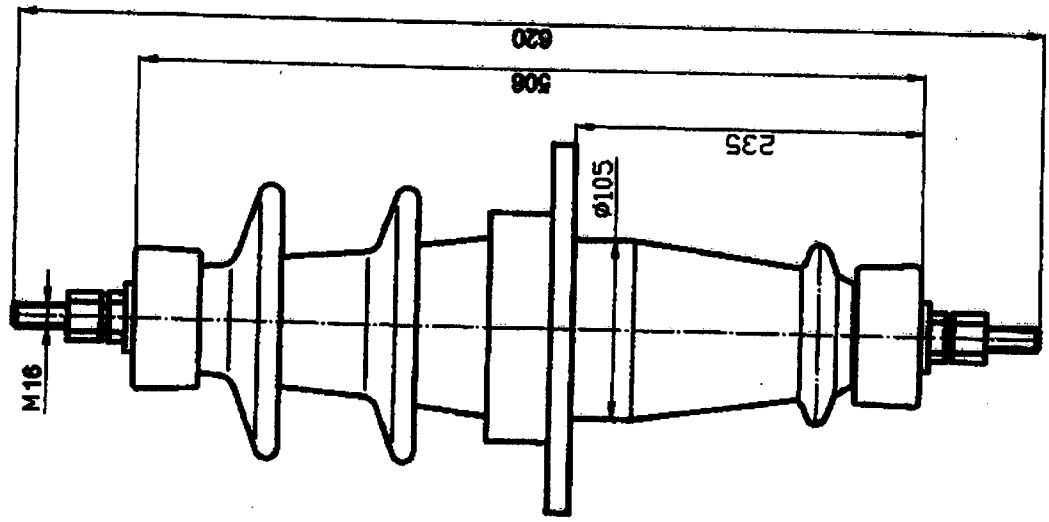


Photo - Aspect of 12 kV, 400 A Indoor/Outdoor Insulated Bushings
in test circuit for temperature-rise test



1. Material: porcelain C110 according to IEC 60672.
2. Colour of glass - brown.
3. Maximum working voltage - 12 kV.
4. Rated current through the bushing - 400A.
5. The general tolerances are according to DIN 40680.
6. Electrical parameters according to IEC 60137.

ND 02.02.02.00	Bushing insulators type PiBO 10/400	"NEOMAT-OLD"



Digitally signed by Habed Gheorghe
Date: 2023.02.24 11:30:44 EET
Reason: MoldSign Signature
Location: Moldova