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THE APPLICATION OF THE THERMO-STIMULATED DEPOLARISATION TSD METHOD FOR THE EVALUATION OF THE PARTIAL DISCHARGE ACTING AT THE POLYESTER FOIL

1. Theoretical basis

The polyester foil effected with the alternating field and partial discharges reveals the polarisation of slow - relaxation type. Alike the thermoelectrets formation [1] there are 2 actions which are forming the foil. The former is connected with the dielectric absorption, understood as the ion movement and the dipole orientation in the polarising electric field. This action leads to the heterocharge creation. On the other hand, the latter action leading to the homocharge creation takes place between the electrode and the foil throughout the partial discharge duration. The electrons and ions settle on the foil surface:next, they penetrate into the polyester interior.

We assume no recombination between the homocharge and the heterocharge. Besides, we assume that the homocharge deterioration is of the relaxation type, while the homocharge disappearance is connected with the dielectric conduction.

Now, it is possible to prove, that the effective charge surface density (or the polarisation state) of the foil changes versus time with the following formula [1].

$$\bar{\sigma}(t) = \frac{\frac{RC}{\tau}}{1 - \frac{RC}{\tau}} \left[\exp\left(-\frac{t}{\tau}\right) - \exp\left(-\frac{t}{RC}\right) \right] \cdot \sigma_p - \bar{\sigma}_o \exp\left(-\frac{t}{RC}\right) \quad (1)$$

where: R - the foil resistance,

C - the foil conductance,

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C – the foil capacitance,

τ – the heterocharge relaxation time,

σ_p – the initial surface density of the charge,

σ_o – the initial effective surface density of the charge (i.e. the sum of the heterocharge and the homocharge)

($t = 0$ is the moment when the foil is delivered from the alternating field and the partial discharge action).

When $RC = \frac{\varepsilon \cdot \varepsilon_0}{G}$ the formula (1) has the following form:

$$\sigma(t) = \frac{\sigma_p}{\tau\left(\frac{G}{\varepsilon\varepsilon_0} - \frac{1}{\tau}\right)} \left[\exp\left(-\frac{t}{\tau}\right) - \exp\left(-\frac{G}{\varepsilon\varepsilon_0} t\right)\right] + (\sigma_p + \sigma_o)\exp\left(\frac{G}{\varepsilon\varepsilon_0} t\right) \qquad (2)$$

The formula (2) presenting the effective surface density of the foil electric charge as a result of the alternating field and the partial discharges stresses is rather complicated. Some important factors are the heterocharge relaxation time value τ and the foil conductance G.

If $\tau \gg \frac{\varepsilon \cdot \varepsilon_0}{G}$

the heterocharge type of the polarisation state changes prevails.

However, for the short relaxation times, the mixed polarisation state can take place: initially of the heterocharge type, next, of the homocharge one. The polarisation state changes versus time are dependent on the initial polarisation state of the hetero type σ_p and on the initial polarisation state of the homo type σ_o as well as on τ and G. The value of τ and G result from the kind of the dielectric foil while the value of σ_o is connected with the intensity and the time of the partial discharge duration. Next, σ_p issues from the value and the direction of the electric field in the moment when the electric field disappears.

Described with the formula (2) the effective charge surface density on the foil time is given in Fig.1 and Fig.2 It begins in the moment when the alternating field and partial discharge actions have been finished. The initial value of the heterocharge σ_p is larger than σ_o: the charges are of opposite sign (Fig.1) or of the same sign (Fig.2).

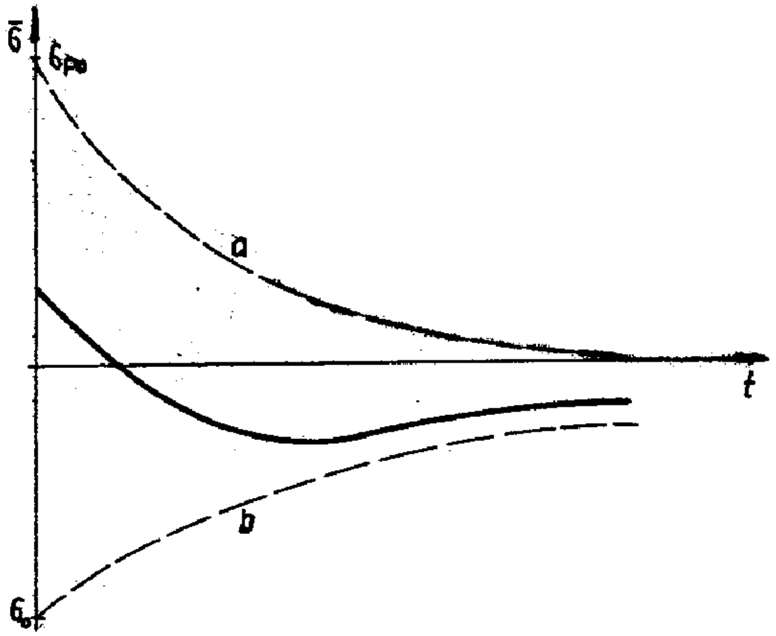

Fig.1. The effective surface density of foil charge vs. time (the foil has been effected with electric field and partial discharges)
a - the heterocharge decay, b - the homocharge decay

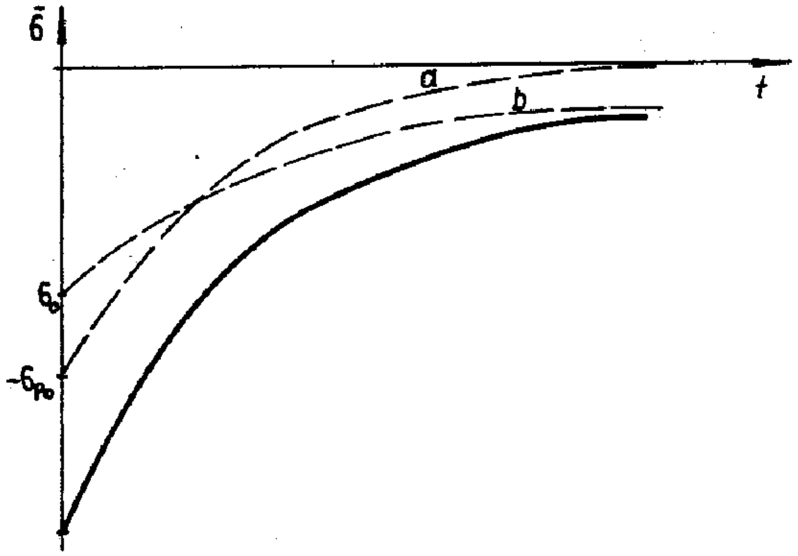

Fig.2. The effective surface density of foil charge vs time (the foil has been effected with electric field an partial discharges: the initial polarisation is negative and of heterocharge type).

So, the foil polarisation state as a result of the electric field and partial discharges action depends on the discharge intensity, on the duration time, on the value and the direction of the electric field in the final moment of action as well as on the τ, G, ε parameters of the foil.

This slow relaxation type of the polarisation state has an important role in diagnostics of the polyester foil insulating systems. This state, changing vs. time and determined with the past of the foil may lead to electric field distribution changes. Consequently, there is the hazard of the insulation fault, especially when the voltage will be switched on once again.

2. The experiments

1. The measurement scheme

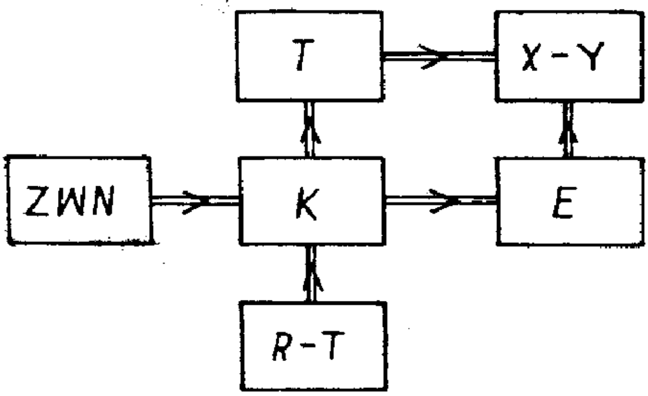

Fig.3. Measurement system scheme
ZWN - high voltage power supply
K - measurement chamber
R-T - temperature control system
E - electrometer
X-Y - register, $I_{TS} = f(T)$

2. The measurement chamber

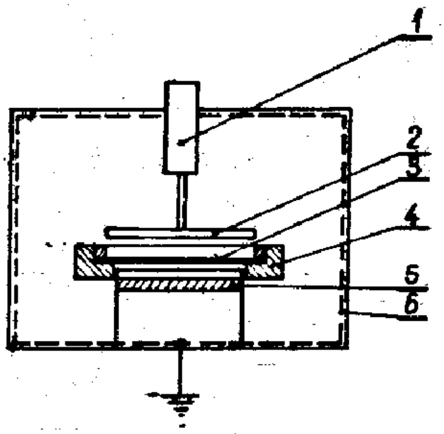

Fig. 4. Measurement chamber
1 - micrometer, 2 - discharge and measurement electrode, 3 - examined foil, 4 - teflon box, 5 - heater, 6 - electromagnetic shield

The sample is mounted in the teflon box this way that after heating by several degrees it is strained and adheres to the heating electrode. It is situated between the earthed plate electrode of 4 [cm] diameter (contacted with it by means of the wet oil) and the high voltage electrode (the insulation is the air layer of 0,3 [mm]).

The electrodes are supplied with alternating voltage of 50 [Hz]. There is a current limitation device to preserve the sample during the discharges in the air. The voltage is switching off with a switch or a control potentiometer in the course of 10 [sec].

Next, the sample is removed from the electrode system. Now, it is subjected to so called free stabilisation (namely, without any effect on its electric state, for example by short - circuiting). Then it is placed between electrodes in the same way as during the first stage of the experiment. The previously earthed electrode becomes a heating one while the high voltage electrodes becomes the measurement one. Now, the thermal depolarisation takes place. Its course described with depolarisation current and temperature is registered with the recorder X - Y.

3. The measurement results

The foil polarisation state has been analysed on the basis of thermo - stimulated current measurements. [illegible] foil has been effected with the alternating field and partial discharges under the following condition:

- the effective voltage between the electrodes: U = 1 [kV],
- the duration time of the alternating current and partial discharges: t = 30 [sec],
- the foil temperature during the partial discharges: T = 25 [°C],
- the distance between the electrodes: d_{ee} = 0,3 [mm],
- the foil thickness: d_f = 10 [μm],
- the stabilisation time (from the alternating field decay till the depolarisation beginning) 0 – 8 [hours],

A – step switching off of the voltage,

B – linear decreasing of the voltage from 1 [kV] to 0 [kV] during the period of 10 [sec].

3.1. The foil polarisation state for the sudden switching off of the voltage, just after decay of alternating field and partial discharges is presented in Fig.5.

Each thermogram regards the separate sample but all have been polarised under the same conditions.

The thermogram dissimilarity results from the differentiation of the electric field values and directions at the moment of switching off of the voltage.

3.2. The foil polarisation state for the sudden switching off of the voltage, 30 [min] after decay of alternating field and partial discharges is presented in Fig. 6.

Each thermogram regards the separate sample but all have been polarised under the same conditions. The courses of thermograms and the current values are somewhat close to negative currents than the former thermograms.

3.3. The foil polarisation state for the sudden switching off of the voltage, 180 min. after decay of alternating field and partial discharges is presented in Fig.7.

The courses and the values of the thermograms are less dispersed than the former one's.

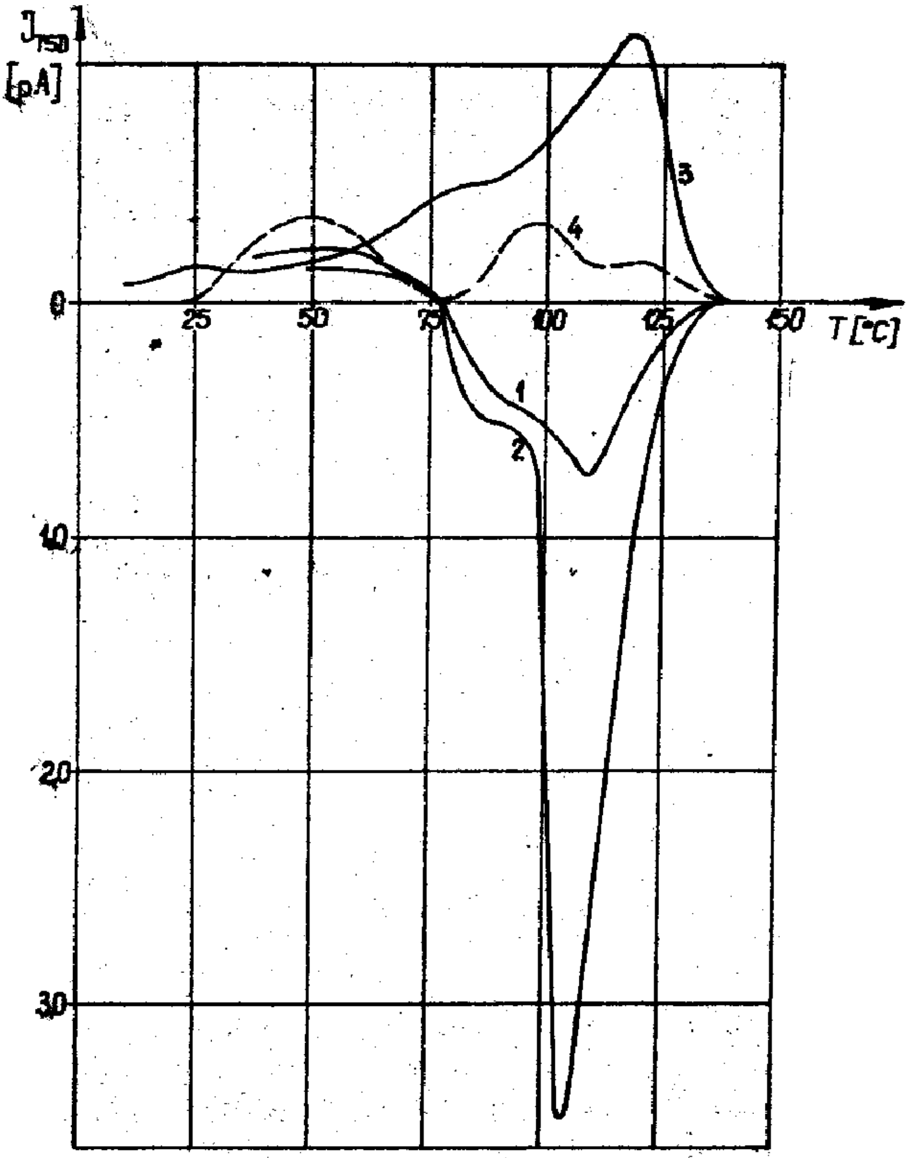

Fig.5. The thermograms of foil samples effected with alternating field and partial discharges. They have been obtained just after the sudden switching off of the voltage, U = 1 [kV], t = 30 [sec].

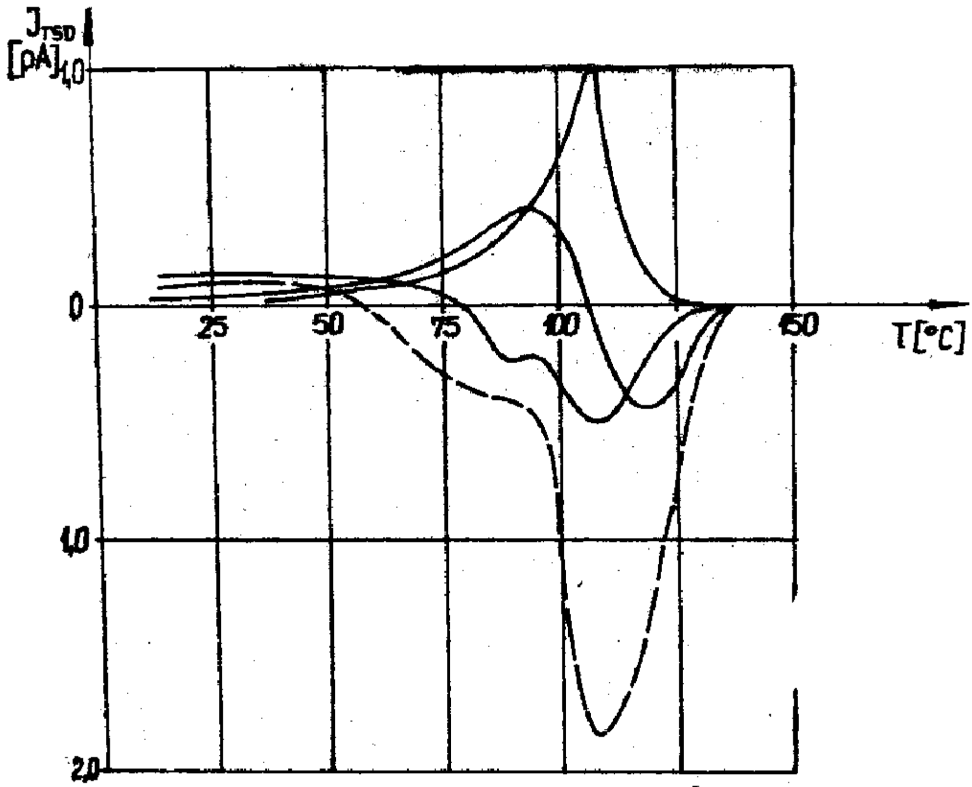

Fig.6. The thermograms of 4 foil samples effected with alternating field and partial discharges. They have been obtained 30 min after the sudden swithing off of the electric field

From this notice it appears that after 3 hours of the stabilisation the effect of the heterocharge on the polarisation state is minimum. So, the heterocharge relaxation time of the polyester foil is smaller than 3 hours (for applied parameters of alternating field and partial discharges).

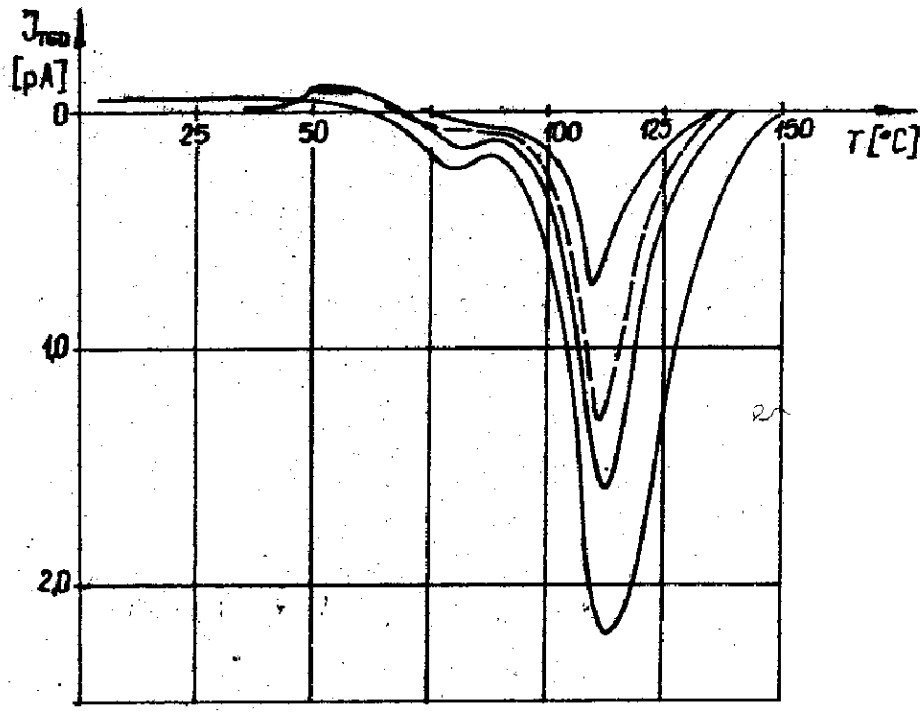

Fig.7. The thermograms of foil samples affected with electric field and partial discharges. They have been obtained 180[min] after the sudden switching off of the voltage U = 1[kV], t = 30[sec].

3.4. The foil polarisation state for the linear decresing of the voltage just after decay of alternating field and partial discharges is presented in Fig. 8.

Each thermogram regards the separate sample but all have been polarised under the same conditions. The courses and the values of the thermograms are insensibly dispersed. It is self - evident that the polarisation state is determined only with the homocharge (created on the foil by partial discharges). There is no thermogram of the opposite properties (contrary to the thermograms for the sudden switching off of the voltage, see Fig.5 and Fig.6). So, the linear decreasing of the voltage excludes the polarisation of the heterocharge type.

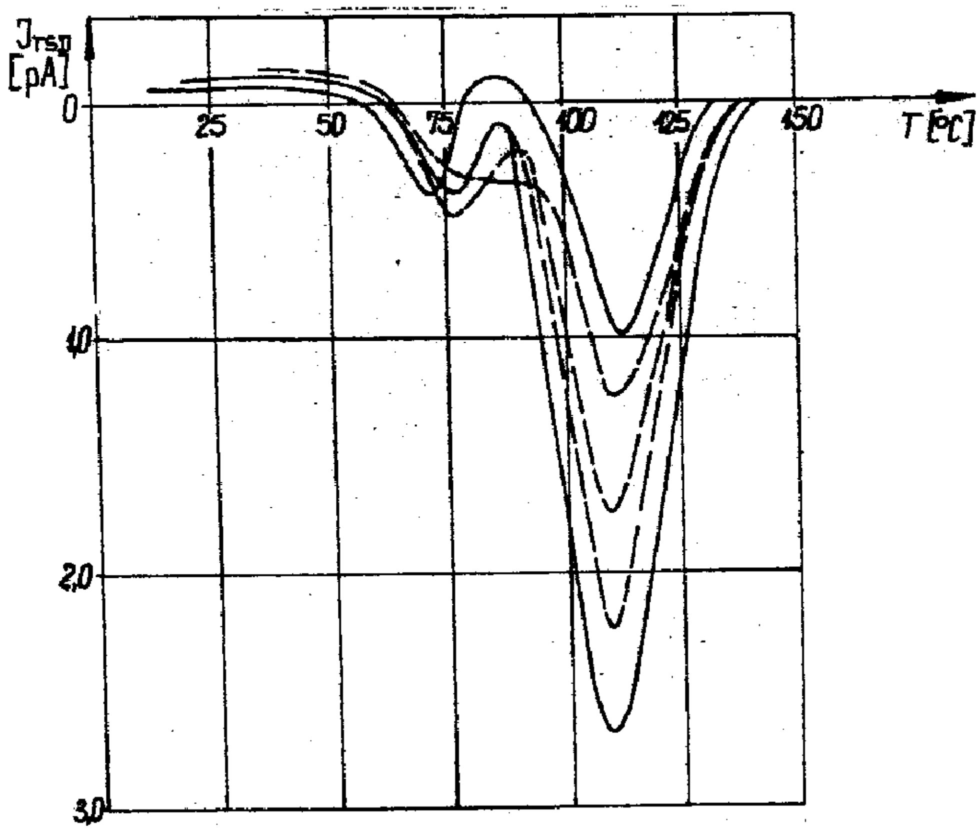

Fig.8. The thermograms of foil samples effected with alternating field and partial discharge. They have been obtained just after the linear voltage decreasing U = 1 [kV], t = 30 [sec]

3.5. The foil polarisation state for the linear decreasing of the voltage 180 min. after decay of alternating field and partial discharges is presented in Fig.9.

The thermograms are close to those of the sudden switching off of the voltage. This leads to conclusion that the decay of the heterocharge takes place before 3 hours. After this time, the polarisation state is determined with the homocharge, created in the foil by partial discharges.

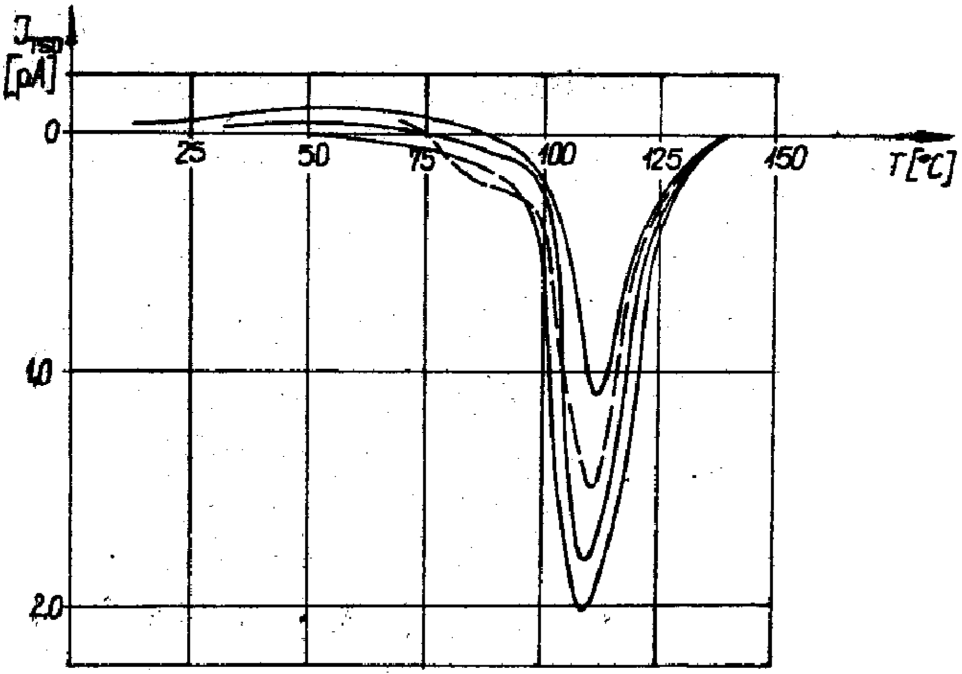

Fig.9. The thermograms of foil samples effected with alternating field and partial discharges. They have been obtained 180 min after the linear voltage decreasing U = 1 [kV], t = 30 [sec].

3. Discussion of the results

The experiments show that the foil polarisation during few minutes after sudden decay of alternating field and partial discharges is determined with the voltage value at the "switching off" moment. The extreme polarisation values are possible: from 0 to the peak value. The thermograms may differ each other: see the courses result from (2) in Fig. 1, and Fig.2.

On the other hand, during the linear decreasing of the voltage, the polarisation state is determined exclusively with the intensity and duration of partial discharges. Moreover, the experiments show that the relaxation time of the dielectric (foil) polarised with alternating field and partial discharges is determined by 2 actions of the charge decreasing (heterocharge and homocharge type). So, if the investigations are limited only to the thermograms just after the switching off of electric field and partial discharges, they may lead to false results.

For example, in Fig. 5 there are 2 distinct peaks for the thermogram No. 4 and the clear bends of the increasing depolarisation current for the thermograms No. 1 and 2.

References

1. Sessler B.: Physics of Electrets. Springer Verlag 1980.
2. Florkowska B., Syrek W., Włodek R.: Badanie mechanizmu samowygaszania za pomocą pomiarów prądów termicznie stymulowanych. IV Symp.: "Problemy wyładowań niezupełnych w układach elektroizolacyjnych" AGH 1983.