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ELECTRIC CHARACTERISTICS OF NUCLEAR POWER PLANT CABLES AT ACCIDENT SIMULATION

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Reseach Institute of Scintific Instruments (RISI) of RF Ministry of Atomic Energy is the Centre of accelerated radiation tests of Nuclear Power Plant (NPP) electrotechnical materials, components and equipments.

The main objectives of the Centre:

1. Carrying out of research works and development of electric insulation aging models at long-term simultaneous exposure of radiation and NPP operating factors (temperature, humidity, pressure, electrical and mechanical stresses and etc.).

2. Development and certification of accelerated test techniques, qualification test perfomance of electrotechnical products and assessment of its lifetime at NPP opeating and accident conditions.

3. Creation of technical state nondestructiv control methods and monitoring means for assessment of electric insulation aging degree and residual life.

4. Accumulation and analysis of investigation and test results, arrangement of Data Bank on radiation resistance and reliability of electrotechnical products and materials for NPP. Creation of complex automated system for prediction of service life and residual life of NPP electrotechnical products.

5. Development of standads and instructions on establishment of general requirements for NPP electric components resistance to radiation and operating stresses; on methodology of qualification tests and lifetime assessment, monitoring and electrotechnical product residual life.

The experimental base of Centre includes the steady-state gamma-neutron reactor, gamma-radiation isotopic sources and climatic chamber complex enabling to carry out tests and investigations under irradiation with dose rates of 1 to 10000 Gy/h under exposure to constant and cyclic operating factors in a wide range of temperature, humidity, pressure, voltage and etc. Centre's technique permits to realize complex diagnostics of actual state of electrotechnical products and construction materials during investigations and tests by measuring:

- electric characteristics: insulation resistance (IR), dielectric strength and partial discharge parameters, capacity (dielectric constant) and angle tangent of dielectric losses;

- mechanical properties: tensile strenght and relative elongation at break, resistance to bending and vibration;

- structural parameters by methods of electron-positron annihilation, differential scanning microcalorimetry, infra-red spectroscopy, differential thermal and thermogravimetric analysis.

The Centre's research programmes are carried out in cooperation with leading institutes developing electrotechnical products, institutes of RF Academy of Sciences, Nuclear Power Plants, Rosenergoatom Concern and Gosftomnadzor organisations.

RISI is currently conducting research on representative samples of NPP cables bouth during long-term aging and accident simulation, since insulated electrical cables are used to provide instrumentation signals, power, or control to virtually all remotely operated power plant equipment. The objectives of this program are to determine the suitability of these cables for extended life (beyond 40-year disign basis) and to assess various cable condition monitoring techniques for predicting remaining cable life. The cables are being aged for long times at relatively mild exposure conditions with various condition monitoring techniques being emploed during the aging process. Following the aging process, the cables are being exposed to a sequential accident profile consisting of high dose rate irradiation followed by simulated desing basis loss-of-coolant accident (LOCA) steam exposure.

This paper presents some results of a study of NPP cables electrical characteristics at normal and accidental conditions.

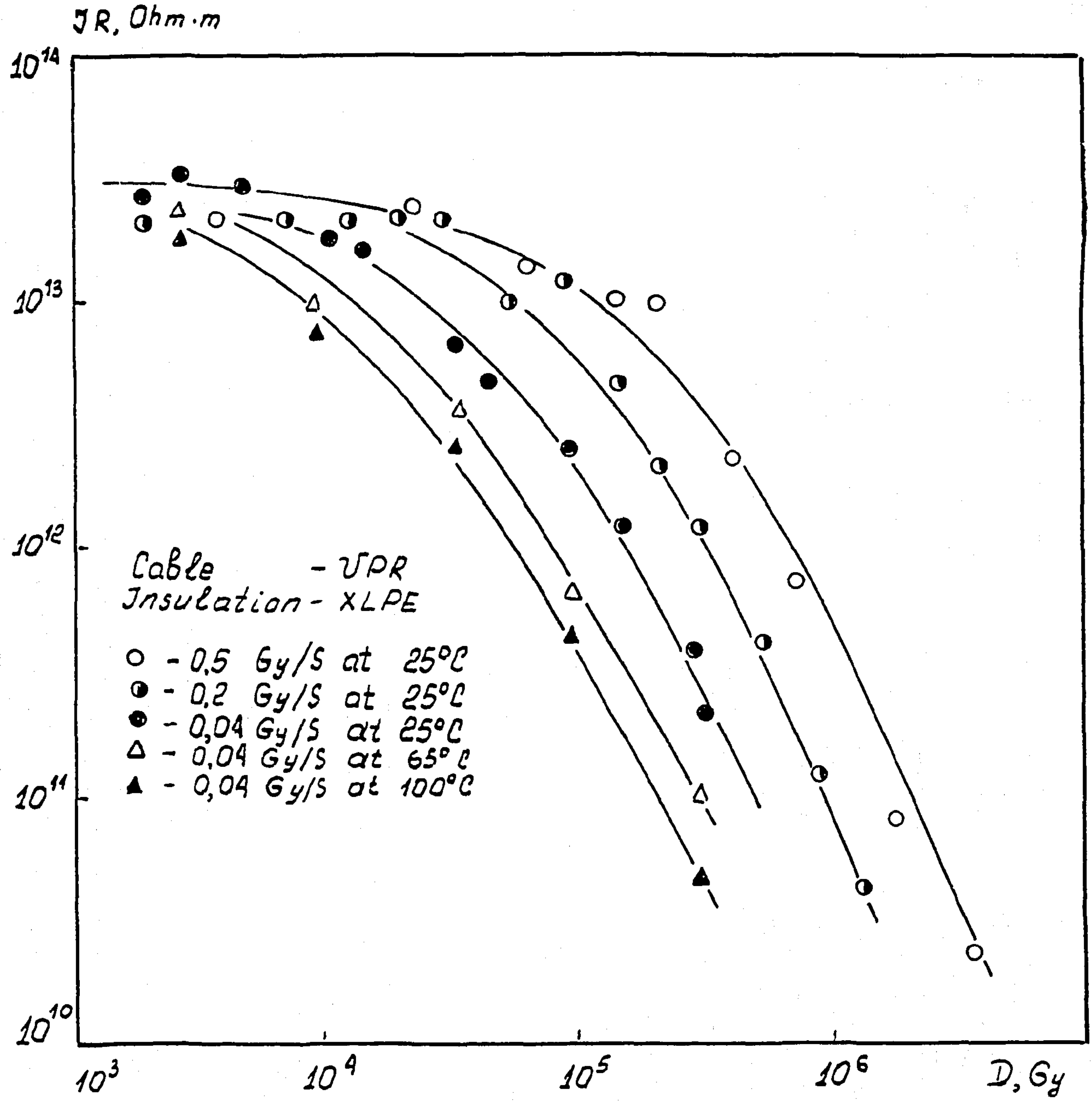
The polymeric cable insulating and jacket materials include cross-linked polyethylene (XLPE), polyvinyl chloride (PVC) and ethylene-propylene rubber (EPR).

XLPE

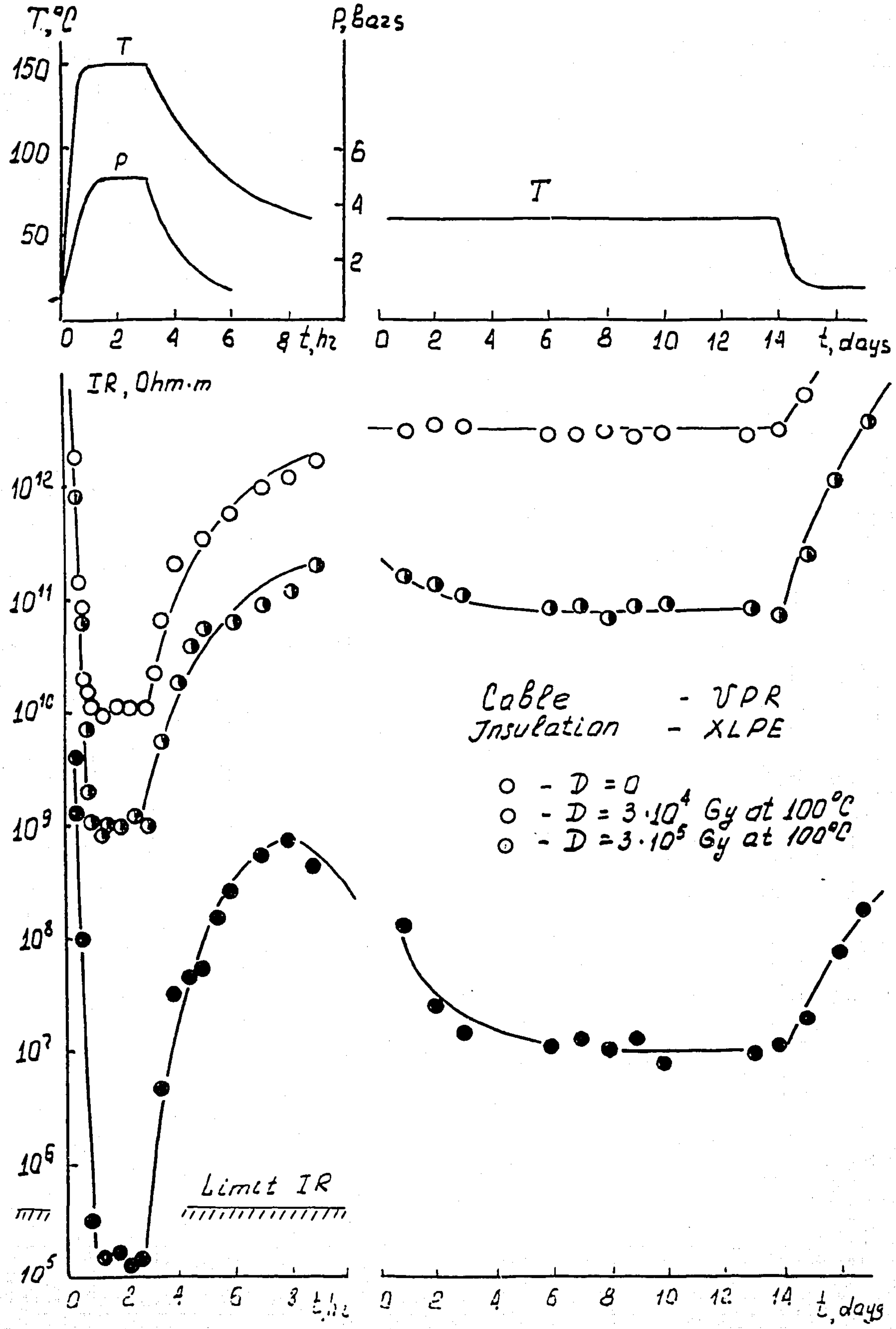
During long - term aging electrical characteristics of these cables (Figure 1) change as a function of the irradiation dose, the dose rate and the temperature. The higher the temperature and lower the dose rate, the greater the degradation for a given dose. Insulation resistance decreasesat the LOCA simulation (Figure 2). The higher the agind irradiation dose, the greater the degradation of IR at the LOCA. For an equal aging irradiation dose, degradation after LOCA is higher for aged cables at lower dose rates.

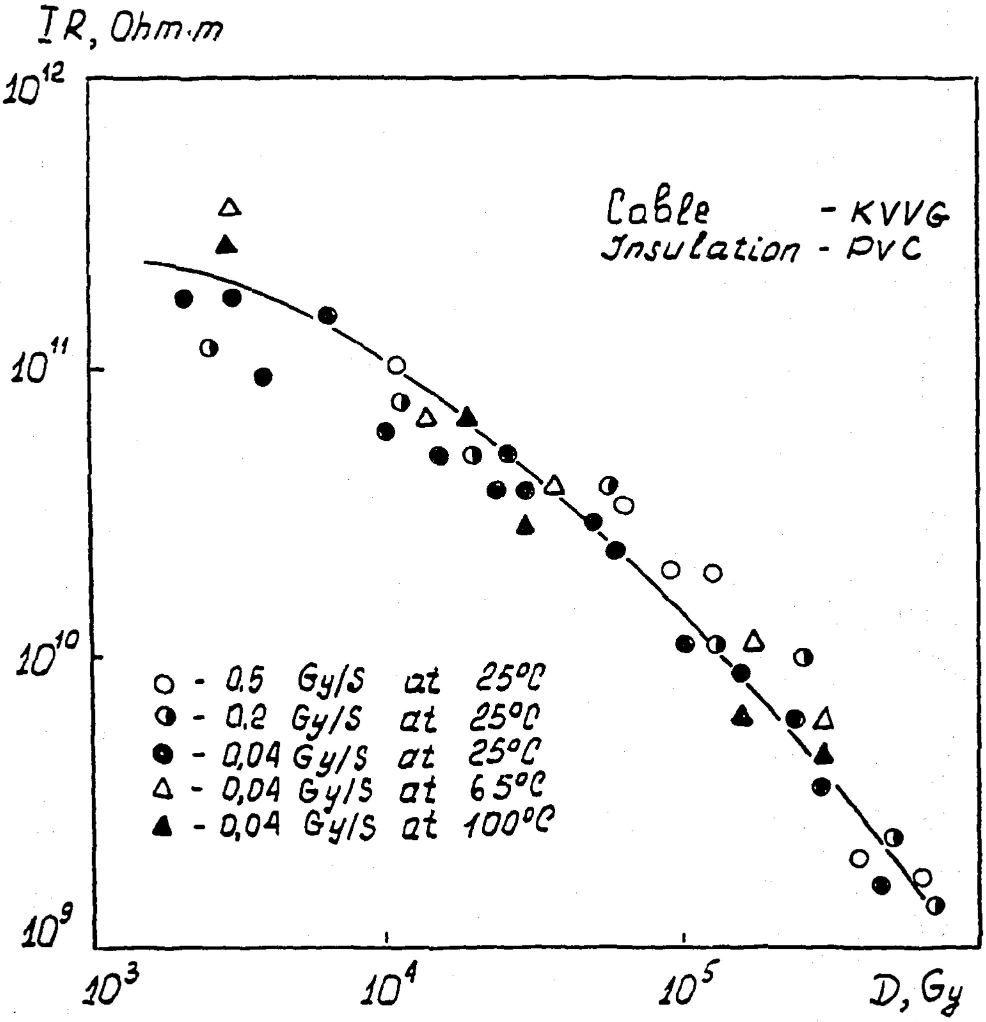
PVC and EPR

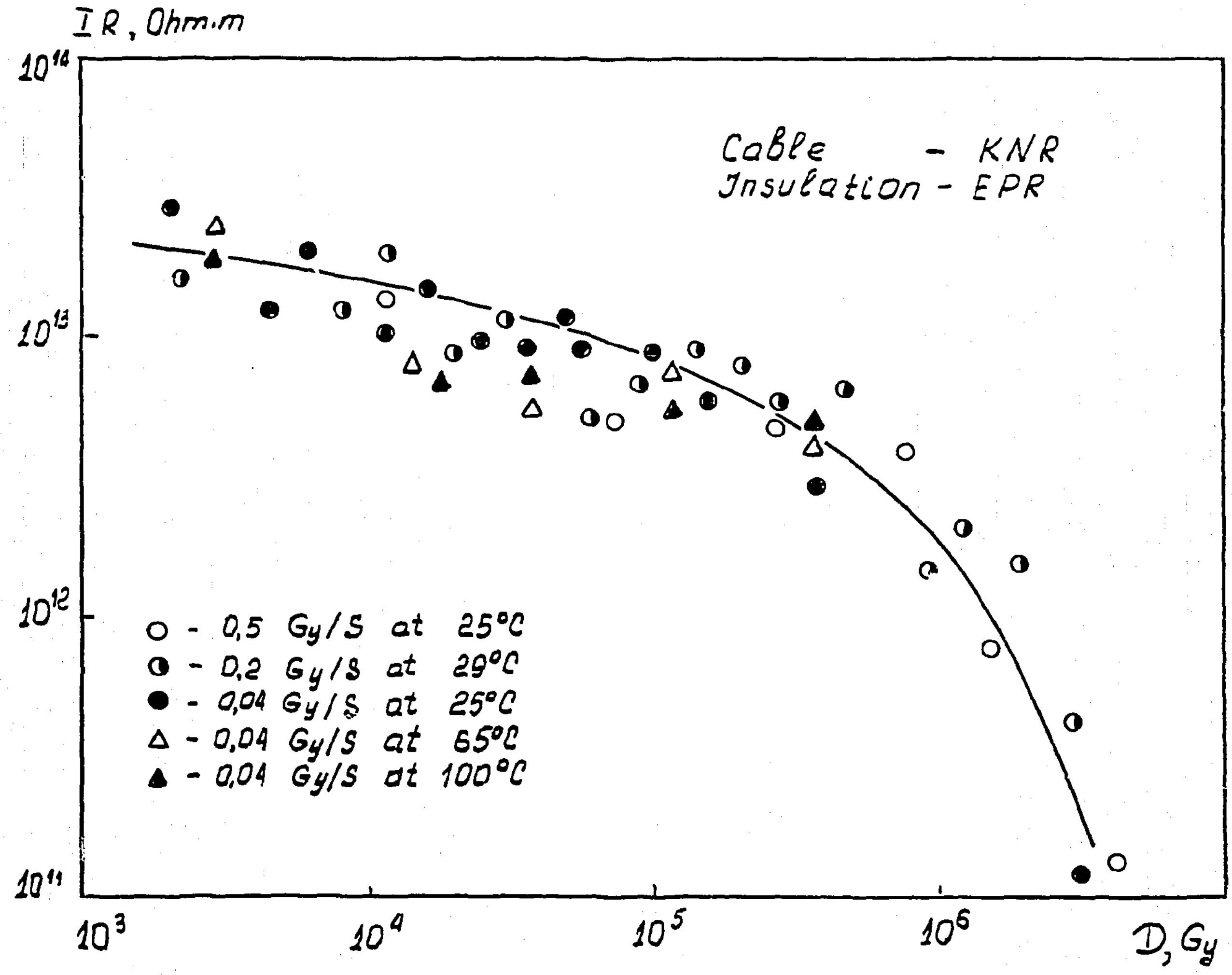
During long-term aging electrical characteristics of these cables (Figure 3,4) change as a function of the irradiation dose and independ of the dose rate and the temperature. Jacket and insulation crack at the LOCA simulation (Figure 5,6). Insulation resistance decrease lower of the limit IR.


IR, Ohm·m
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
10^3
10^4
10^5
10^6
D, Gy
Cable - VPR
Insulation - XLPE
○ - 0,5 Gy/S at 25°C
◑ - 0,2 Gy/S at 25°C
● - 0,04 Gy/S at 25°C
△ - 0,04 Gy/S at 65°C
▲ - 0,04 Gy/S at 100°C

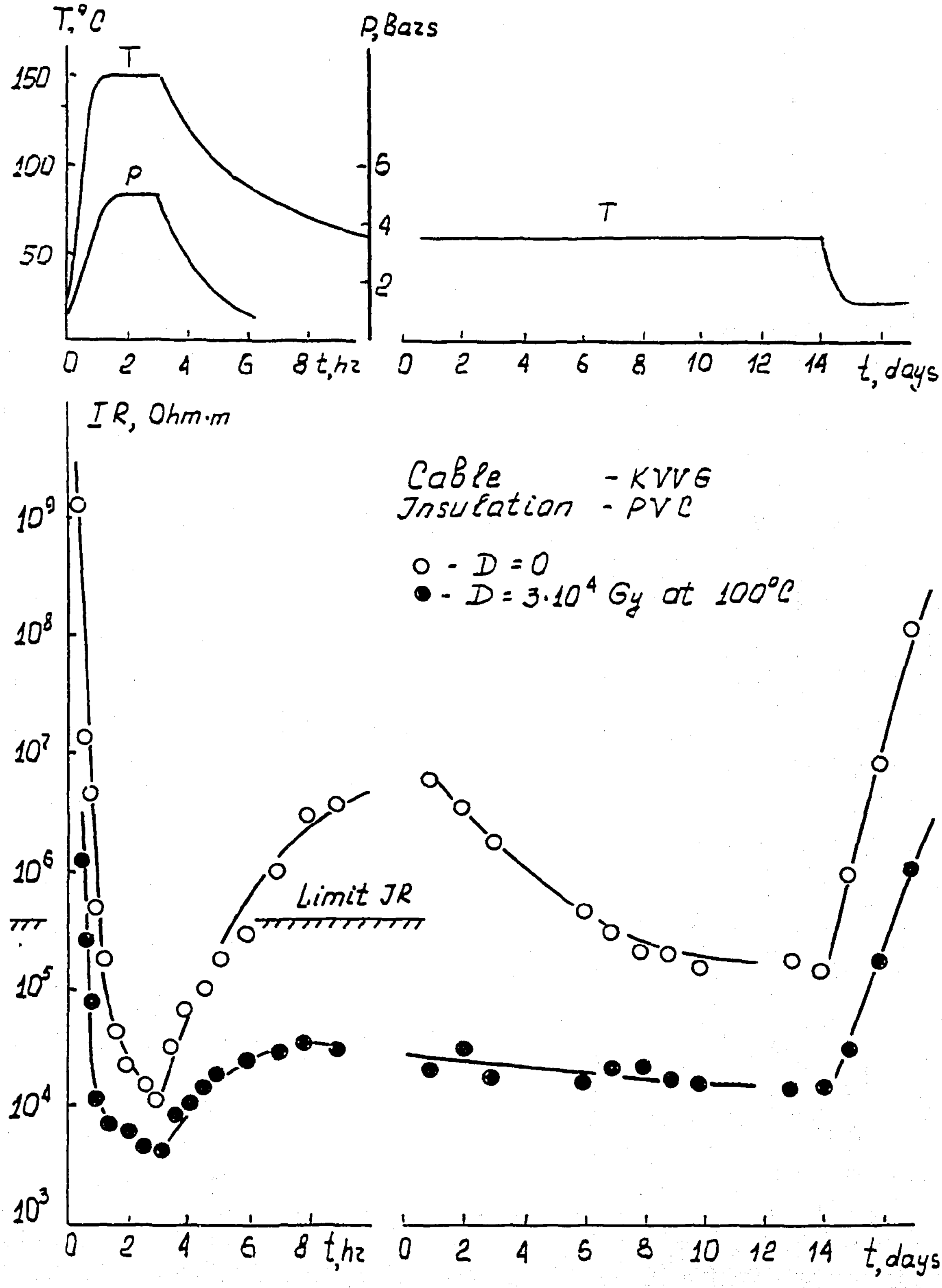
LOCA and POST LOCA profiles




IR, Ohm.m
10^{12}
10^{11}
10^{10}
10^{9}
Cable - KVVG
Insulation - PVC
○ - 0.5 Gy/S at 25°C
◐ - 0.2 Gy/S at 25°C
● - 0,04 Gy/S at 25°C
△ - 0,04 Gy/S at 65°C
▲ - 0,04 Gy/S at 100°C
10^{3}
10^{4}
10^{5}
D, Gy


IR, Ohm.m
10^{14}
10^{13}
10^{12}
10^{11}
Cable - KNR
Insulation - EPR
○ - 0,5 Gy/S at 25°C
◐ - 0,2 Gy/S at 29°C
● - 0,04 Gy/S at 25°C
△ - 0,04 Gy/S at 65°C
▲ - 0,04 Gy/S at 100°C
10^3
10^4
10^5
10^6
D, Gy

LOCA and POST LOCA profiles



LOCA and POST LOCA profiles