NEUTRON IRRADIATION AND TEMPERATURE EFFECTS ON INDUCED VOLTAGES IN VARIOUS MINERAL INSULATED CABLES AND CERAMIC-COATED WIRES

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Magnetic diagnostics in tokamaks relies to a large extent on in-vessel magnetic coils, made from mineral insulated (MI) cables or ceramic coated wires. In ITER, these coils will have to operate in rather high radiation fields and significant thermal gradients. In order to minimize the impact of these conditions on magnetic coil measurements as well as on other tokamak diagnostics using similar cables, the physical processes involved should be fully understood.

In order to study these processes, U-shaped single copper and stainless steel core MI cables (with outer diameter 1.0 and 1.5mm), dual copper and stainless steel core MI cables and three types of mineral coated wires have been irradiated in the BR2 reactor. The cables were guided through a 25 cm long double wall tube to create significant temperature gradients during the irradiation or during reference measurements at zero flux using electric heating. The induced core-to-sheath currents and the voltages between both core ends were continuously measured.

The amplitudes of the various delayed contributions to the currents are in good agreement with model data and can be attributed to the beta rays emitted upon decay of activated Cu and Mn in the cables and their surroundings. The prompt current amplitudes depend strongly on the orientation of the rig inside the channel. During the first days of irradiation the prompt component amplitudes of some of the cables showed a significant drift. Similar prompt current characteristics had been observed before in 1 mm diameter MI cables [1].

Significant differential core-to-core voltages were observed, up to 8 µV at the final fluence. A clear correlation exists between the temperature gradients and the voltage, so the observed voltages can be unambiguously interpreted as due to the Seebeck effect. However the magnitudes of the Seebeck coefficients clearly evolved during the irradiation. The observed core-to-core voltage data for the single copper core MI cables and for the EXPOCABLE (mineral coated copper wire) are consistent with a Seebeck coefficient that is proportional to the local neutron fluence, with a proportionality factor of about $2 \cdot 10^{-21}$ (µV/°C)/(n/cm²) which can be attributed to thermal neutron induced transmutation of Cu into Ni. This result is in perfect coherence with the data in [1]. There is hardly any difference in behaviour between the MI cables with different diameters or between the MI cables and the copper EXPOCABLE. In the dual core cable, the thermoelectrical effects from the two legs of the core wire cancel almost completely, due to the identical accumulated neutron fluence profiles over the two legs experiencing compensating temperature gradients.

For the stainless steel core cables the data indicate a fast increase of the Seebeck coefficient at low fluences, but the thermoelectric sensitivity was observed to saturate quickly (at a local thermal neutron fluence of about 10^{19} n/cm²). The evolution of the voltages can be described quite well by assuming a Seebeck coefficient which grows in exponentially with the neutron fluence and with a final value scaling with the local temperature during irradiation. These results confirm the interpretation of the data for the stainless steel core cable in [1]. Again the MI cable diameter effect is small and the dual core cable voltages are very small.

[1] L. Vermeeren and M. Wéber, “Induced voltages and currents in copper and stainless steel core mineral insulated cables due to radiation and thermal gradients”, Fus. Eng. and Design 82, 5-14, 1185-1191 (2007)