Box 2: Development of Charging Belts in Russia

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Charging systems based on charge-carrying belts have been one of least reliable components of Russian electrostatic accelerators. The main disadvantages of existing belts are their short lifetime and the considerable wear of the working surface. Owing to the short lifetime of the belts, it has not been possible to use the experimental equipment effectively, and additional expense has been required to purchase the gas insulating mixture. The high wear of the belt increases the content of dust in the insulating gas considerably, as well as the dust deposition on the surface of the high-voltage structure, thus reducing the dielectric strength of the accelerator. Under these circumstances, it is also impossible to use a contact method for applying and removing charges. A belt made of rubberized cotton fabric has a high hygroscopicity; this prolongs the time needed to condition the belt. In addition to these disadvantages, the stiffness of the belt is insufficient, and therefore the position of the belt is unstable, resulting in high-voltage instability of the accelerator. The strength of interlayer connection is rather low (880 N/m), which very often leads to belt failures. In order to develop a reliable belt, long-term studies have been carried out at our institute in Obninsk. Many different types of synthetic, cotton and combined fabrics have been tested.

The type of belts tested at the beginning had a very high mechanical strength and wear resistance. However, their dielectric strength was rather low. When they were used, some of the fibers located in the warp of the belt burned out. The reason for the decrease of dielectric strength of the belt was finally found by tests carried out at different accelerators. Discharges occurring along the belt were found to be caused by interlayer cavities formed in some sections of the belt as a result of insufficient gluing of the different layers.

Some of the belts made with a synthetic warp showed a rather high relative elongation (more than 3%). In some accelerator designs, it is impossible to use belts with such an elongation. During the development and tests of the different belts, some other failures took place, resulting in a decrease of the charging performance.

In order to ensure high dielectric and mechanical strength as well as a permissible relative elongation value (less than 1%), a combined cotton–polyester fabric is now being used as a warp. Raw rubber for the rubber mixture was chosen from the standpoint of ensuring wear resistance, mechanical strength and the appropriate electric characteristics.

Production of 1.2 to 3 mm thick belts with two, three or four layers has been launched. The working load of a 550 mm wide four-layer belt is about 7.9 kN for each of the two parts of the belt, while the load of a two-layer belt about 200 mm wide is about 4.9 kN. Seamless belts of up to 6 m full length can now be manufactured. Belts with a length over 6 m are manufactured using a connecting seam.

Charging belts of the latter type are used at the Obninsk accelerators and in accelerators at other Russian research centers. The methods of applying and removing charges utilized (either by charging needles or contact methods using grids and foils) vary. At all accelerators operating with these belts, a special design approach is used for applying and removing charges on the inner surface of the belt.

Table B2.1. Some results on tests on rubberized fabrics for belt charge conveyors

No.	Characteristics	Type 236	Type 1590-1
1	*Design*		
1.1	Number of layers	4	4
1.2	Base (fabric)	Percale	Cotton fabric with polyester
1.3	Type of (raw) rubber	Natural rubber	Methyl styrene synthetic rubber (MSSR)
1.4	Belt thickness (mm)	1.4	2.8
2	*Mechanical characteristics*		
2.1	Rupture force applied to 50 mm width strip (kN)	0.83	1.9
2.2	Strength of interlayer connection (kN/m)	0.88	1.67
2.3	Strain for 9.81 kN/m tension (%)	3	1
2.4	Wear resistance		
2.4.1	Duration of tests (hours)	42	1200
2.4.2	Equivalent time of accelerator operation	296	10 000
2.4.3	Lifetime of the belt in an accelerator	300–500	8000–10 000
3	*Electrical properties*		
3.1	Surface breakdown under atmospheric conditions (kV/cm)	14.9	14.8
3.2	Surface resistance (ohm/mm)	1.2×10^{11}	1.5×10^{12}

For instance, at the EGP-15 tandem accelerator in Obninsk, the contact method for applying the charge is based on a 100 μm thick stainless steel foil. The belt was installed in the accelerator in 1989, and after running for over 11 000 hours, its condition today is still quite good. The maximum working gradient of the potential along the belt is 1.5 MV/m. The same type of belt has been used at the EG-5 single-ended accelerator in the Neutron Physics Laboratory of the Joint Institute for Nuclear Research in Dubna since March 1997. In this accelerator, the contact method is used for charging the belt. The belt has been used more than 8500 hours and is still in good shape.

Different types of belts and their materials were tested at high-voltage in our experimental facilities. The belts were tested for rupture, stratification, dielectric strength and wear resistance. In order to test the belts for wear resistance, belt material samples were stuck on a pulley driven by the electric motor, and a contact system ensuring the required hold-down force was provided. The results of the tests are presented in Table B2.1. These results show that the new belt has high electric and mechanical characteristics, as well as high wear resistance.

It is my pleasant obligation to express sincere appreciation to my colleagues V.I. Spirin and V.V. Ecomasov for their help in carrying out the tests on the various belts.