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Investigation of a New Type Charging Belt

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ABSTRACT

There are many desirable characteristics for an electrostatic accelerator charging belt. An attempt has been made to find a belt that improves on these properties over the stock belt. Results of the search, procurement, and 1500 hours of operational experience with a substantially different belt are reported.

1. Background

Among the desirable characteristics of a belt used to charge an electrostatic particle accelerator terminal are: charge carrying capability, dielectric strength, wear resistance, mechanical strength, resistance to damage from the accelerator environment, immunity to damage from discharges, little or no dust production, and reasonable cost. Another very important quality is consistency of manufacture in regard to electrical and mechanical properties throughout the length of individual belts. This facilitates achieving low belt induced ripple. Consistency from one belt to another is also significant. This provides the user with a dependable supply of new belts that provide predictable results. Over the years, the proceedings of this body have chronicled many discussions about belt consistency.

The EN Tandem accelerator at Oak Ridge National Laboratory (ORNL) operates to support a varied program of atomic physics research. As such, the demands on the accelerator often require a range of operation from ~0.38 to 7.0 MV on the terminal, with low ripple and long term steady state operation. The standard charging belts obtained from the manufacture have generally given acceptable performance, but it is reasonable that modern manufacturing techniques and materials could increase belt lifetimes and improve accelerator performance, particularly voltage ripple.

In the Spring of 1993, the accelerator began to provide unacceptable performance due to belt induced terminal ripple. The overall ripple had increased to more than 30 kV at 2 MV, that the terminal potential stabilizer could not correct. Similar problems had been experienced previously that were temporarily corrected by cleaning the belt, but this mend never lasted for more than a month. A more long term solution was needed. Observation of the belt running in air indicated that it was mechanically out of balance, causing it to "flap" no matter what tension was applied. Terminal ripple power spectrum analysis revealed that, although there was a ripple component at ~31 Hz corresponding to the vulcanization lap joints, by far the most dominant and troublesome ripple was at ~3.125 Hz (the belt frequency for this EN).

2. Search For Alternative Belt

Previous experience with urethane rubber as a belt repair material led to a survey of belting manufacturers to see if a belt could be made that was : (a) continuously woven to prevent joint problems as experienced with the gray belt popular in Europe,

(b) covered with a urethane product with appropriate properties for a charging belt, and (c) produced with modern manufacturing techniques that were more inherently consistent in quality and uniformity of product.

After several weeks of telephone discussions and catalog searches, A company was found that would happily produce a belt of continuously woven polyester yarn carcass covered in a continuous process with a wide choice of coatings applied in a continuous process to whatever thickness specified. They could build the belt to the exact dimensions of a standard EN belt.

3. Procurement

The company chosen was Ammeraal Inc. of Grand Rapids, Michigan. An order was placed for a 9.0964 m long, 528 mm wide belt type 109 of endless woven (GK) polyester with .5 mm top and .3 mm bottom coatings of Ropanyl - a trade name for urethane. The total weight of the belt was about 20 lb. For comparison, an EN belt of standard construction weighs about 43 lb. The delivered price including air freight from their plant in The Netherlands was $2748.82 US. As reported last year, it arrived two days before SNEAP '93. Total time from order to delivery was five weeks.

4. Installation and Testing

The new belt was installed on 17 November 1993. It went in with slightly more ease than the standard belts, due mainly to its reduced weight. Installation without removal of our top mounted resistor string required only a quick spark gap alignment check and removal of arm hairs from lock washers. The drive motor and alternator were replaced with spare units containing newly installed sealed bearings. Initial run-in was easy after discovering some miswired thermocouple leads. As usual, the upper bearing ran uncomfortably warm at first, but after ~6 total hours of running came down to a reasonable value of about 170° F. The old shim stock charge applicator, collector, and down charge wiper were then installed. Inner belt guides were not re-installed . The plain guides without ceramics had been removed several years ago, and the machine seemed to run better without them. This time the decision was made to try removing them all. Ripple was measured and belt tension reset several times. It was obvious that the shorted terminal ripple was no better than with the old belt.

After many shim adjustments the tank was closed to see what ripple at voltage would look like, and if the belt could transfer sufficient charge and hold voltage. With around 90 psig of 64% N_2, 16% CO_2, 20% SF_6 gas mixture, The belt transferred 400 microamps to the terminal out of 450 microamps applied. Of the charge not transferred, most was returning to the down charge wiper. The machine was conditioned at our normal rate, and in several days the machine was up to 5.6 MV. During this time, one dozen sparks were recorded .

5. Early Operational Experience

The machine was turned over to experimenters for a two-hour, 2 MV experiment, then it was opened to locate the cause of the sparks. A phenolic hoop sliding tool had fallen behind the tube on the high energy end. It was removed, and the tank closed again. After gassing back up to about 85 psig, conditioning recommenced. The first spark was at

5.7 MV, and seemed to be induced by conditioning activity. Sadly, all succeeding sparks were at progressively lower voltage. When it sparked twice at less than 4 MV, the decision was made to opened the tank again.

Along the length of the belt was evidence that one or more sparks had traveled the column, jumping from belt guide to belt at every other plane. Each spot indicated that a small amount of material had melted and smeared along the belt by the shims. Although this was glaring condemnation, I surmised that the snowy white belt told tales a brown belt kept secret. The inner insulated belt guides were reinstalled. Since more down charge was being observed than normal, we experimented with wipers in different locations with the goal of reducing lost and circulating charge, and reducing ripple. The terminal wipers were modified by changing from shim stock to 100 mesh stainless screen. A shim stock wiper was added at the mid point of the alternator. Others were placed on the inside of the belt at the exit of the terminal and as the belt leaves the drive motor entering the column.

After closing and gassing to 68 psig, the machine ran at 1.5 MV in slit control with a total ripple of 540 volts RMS. This fine operation at terminal potentials <3MV continued until mid March, when a return of ripple caused me to try adjusting the belt tension. Although this returned the good ripple performance, it was a mistake. In April the machine was opened because it was sparking at less than 2 MV. The belt had been run off the alternator at the terminal (as yet there is no viewing system to avoid this) About 1/8 inch of belt had been chewed off the bottom by running it against the lower trunion block. There was white fuzz all over the place! Only 400 hours into its life and this belt was getting some rough treatment. Belt tension had dropped to less than 1000 lb. total.

The majority of white plastic was cleaned out of the column and tank, and once again the belt was retensioned and retracked at the terminal. The machine was closed, and all of the gas on hand was added, bringing the tank pressure to only 68 psig. The machine was then turned over to the researchers. For the next 1100 hours the machine ran flawlessly from 0.38 to 4.0 MV. The unregulated (terminal stabilizer in Standby, corona probes withdrawn) ripple at 4.0 MV was 800 volts RMS total for 0 - 50 Hz. Belt tracking, by observation of position on the drive motor, did not change.

6. Present Conditions

At 7:30 PM on 30 August 1994, the operator paged me to complain that the ripple had suddenly jumped to 80 kV. After finding no external reason, the machine was opened. Once again, piles of plastic 'fuzz' were found all over the machine. The belt tension was checked, as well as screen position and quality, and a visual inspection made of the entire column. A clog of belt fuzz trapped under the terminal charge collecting screen appears to be the cause for the sudden increase in ripple.

The belt does not look good. Along its length are varying indications that the surface of the coating has melted and smeared material along the belt. Still, it is white and shows defects much more readily than the old belts. Much urethane 'dust' has spread over the column in the vicinity of the belt. The majority of this is believed to be melted urethane that did not remain adhered to the belt.

The majority of belt particles are just after the mid section on the belt's down run side. This was a problem with the old belts, too. Various sized wire brushes available for gun cleaning work well to scrub away stubbornly adhered urethane.

Another call was placed to the belting manufacture. They indicated that the urethane used to make our belt only has a "maximum product contact" temperature of 195° F. This was not a property that was specified in our order, as I had foreseen no problem in this area.

This machine's drive motor bearing temperature runs as high as 200° F during bearing run-in. Normal temperatures fall to ~120° F in gas. In the past, drive motor pulley surface temperatures were recorded during bearing run-in that exceeded 200° F. Surprisingly, the inside of the belt looks unblemished.

High temperatures that could cause this melting might come from either a component such as a belt guide or charging shim heated by friction or the temperature of the charging corona. I had thought that the shims should fly on a cushion of gas driven by the belt. Certainly the shims did not show evidence of rubbing material from the belt, but they were stropped to a razor edge by the belt.

7. Conclusions

This new belt exhibits many desirable properties. It carries charge well. It has operated to 5.7 MV in our EN, and should be capable of being used at much higher voltages. It shows very little wear after 1500 hours of use. It can carry the normal belt tension, although the optimum tension may be lower due to the reduced weight of the belt. It was inexpensive and delivery was very rapid. It provides very low ripple charging when it is working well. The quality of construction appears to be very good, and very consistent. Since the belt is made in a continuous process it should be very homogeneous, and quality from one belt to another should be uniform.

The belt also has some disappointing faults. It has been very difficult to maintain properly tracked and tensioned without a method of viewing the terminal end. This is probably due to the polyester carcass. Dust (from mechanical wear) production is no better than with the old rubber belts. The greatest problem, however, was one that I did not anticipate. The low melting point of the covering material has allowed rapid degradation of the exterior surface. This degrades ripple performance and may limit voltage holding capabilities. Future plans are to pursue a higher melting point covering for the belt, with perhaps a change in weave to stabilize the stretch of the belt.

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